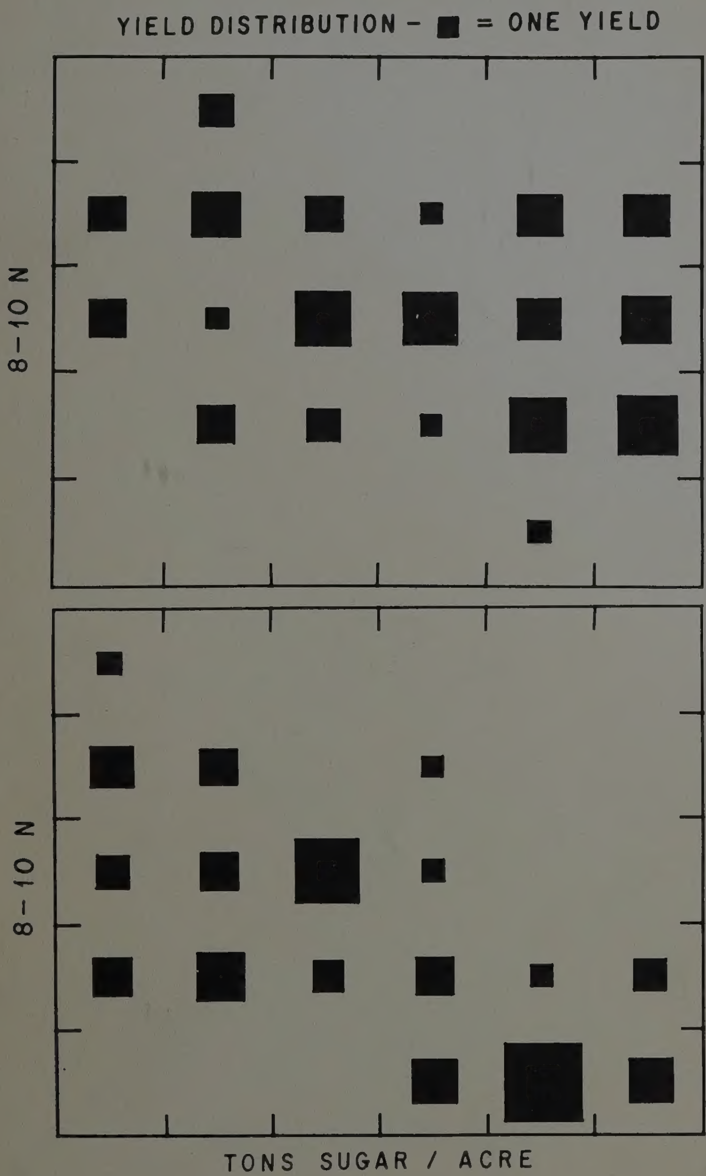
HAWAIIAN PLANTERS' RECORD



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HAWAIIAN PLANTERS' RECORD

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A publication devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among plantations of the Hawaiian Sugar Planters' Association.

On the Cover: Scatter diagrams showing relation of sugar yields to 8–10N
(See pages 54 and 55 for details)

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PLANT AND SOIL COMPOSITION RELATIONSHIPS AS APPLIED TO CANE FERTILIZATION

L. D. BAVER *

INTRODUCTION

Field plot experimentation was initiated early in the history of the Hawaiian sugar industry to establish principles in the fertilization of sugar cane. Replicated field experiments still remain the major reliable means for providing basic data upon which to establish a fertilization program. However, it has long been recognized that supplemental soils and plant information can be of valuable assistance for explaining the results of field-plot experimentation and for extrapolating the findings to other locations for practical usage. The Mitscherlich pot method of determining nutrient needs was initiated in 1929 and used to some extent until 1950. Acid-soluble phosphate and potash analyses were made as early as 1919 to delineate deficiency areas. They were used to a small extent until supplanted in the early 1930's by rapid chemical soil analyses. The latter were used extensively with rather good success until they, in turn, were supplanted by more precise chemical methods. In the late 1940's, a modified Truog procedure was developed for available soil phosphorus. Available soil potassium and calcium were measured by the ammonium acetate base-exchange techniques.

The first attempt to link fertilizer recommendations with plant composition was the use of crusher juice analyses in the early 1920's to evaluate the phosphate and potash needs of the soil. Then in 1930, the Experiment Station made a rather thorough study during the life of the crop of the chemical composition of certain parts of the cane plant. The development of the leaf-punch technique in 1937 and the initiation in 1938 of a cooperative study with the University of Hawaii on the application of crop logging to sugar cane accelerated both the research on plant and soil composition as indexes of nutrient needs and the employment of composition values for practical plantation usage.

As often is the case in the progress of scientific research, differences in interpretations of soil and plant analyses originated within the industry. In order to provide more basic information on soil and plant composition interrelationships as they affect fertilizer recommendations, a rather comprehensive group experiment was set up in 1952. It involved seven plantations, covering rather wide differences in soil and climatic conditions. The objectives and plan of the experiment are given in Appendix B. Statistical analyses of the yield data are discussed in Appendixes C and D.

This publication presents the data and conclusions from Experiment Station, HSPA, research as objectively as possible in the hope of clarifying some of the confusion existing in the use of plant and soil analyses for making fertilizer recommendations. The data are being presented in graphic form with attached concise comments. No attempt has been made to elaborate on the various points.

* Director, Experiment Station, HSPA.

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This number of the Hawaiian Planters' Record could not have been possible without the cooperative help of a large number of individuals. The Director wishes to thank most sincerely the following for their many contributions:

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   See individuals listed in Special Release No. 116, page 89.

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   See individuals listed in Special Releases No. 116A and 116B, pages 95 and 143.

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5. For the soils data and related charts—
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   Warren Gibson, Principal Industrial Engineer.
   Daniel Dougherty, Senior Industrial Engineer.

7. For reproducing the many graphs—
   L. K. Quemuel, General Draftsman.

SECTION A

CHEMICAL COMPOSITION OF CANE PLANT PARTS

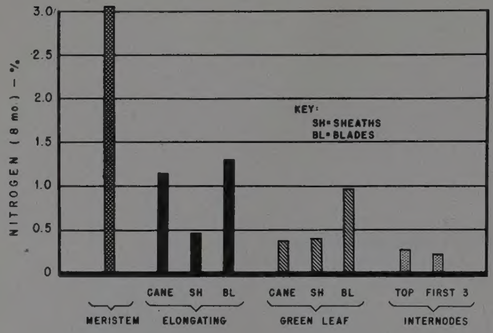


Figure 1. The nitrogen composition of cane tissues (after Clements, Haw. Planters' Record, 44:201, 1940).

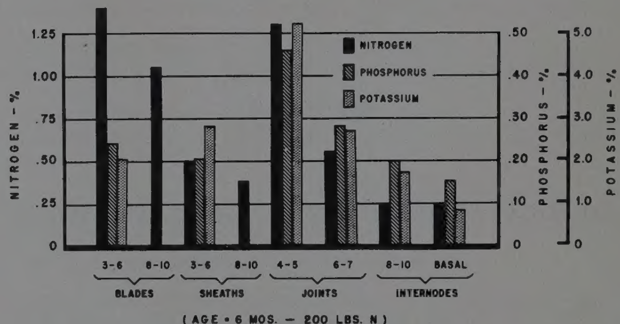


Figure 2. Nitrogen, phosphorus and potassium composition of cane tissues (after Burr and staff, HSPA, Exp. Sta. Rpt. 1959, p 14).

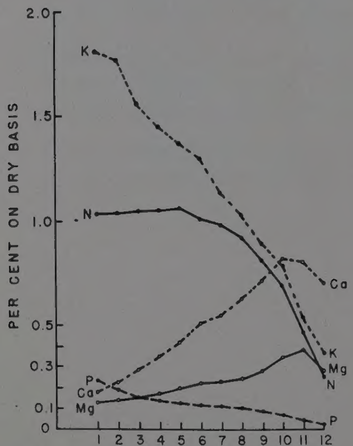


Figure 3. The composition of major nutrients in cane blades at 10½ months (after Tanimoto, unpublished data). (Abscissa represents leaf number, counting down from the top.)

The data presented in Figures 1 and 2 show rather clearly the distribution of N, P and K throughout the major parts of the cane plant. Figure 3 illustrates the composition of leaves of different ages when the whole plant was ten and one-half months old. The data may be summarized as follows:

1. Nitrogen values are highest in the younger parts of the plant, such as the meristem tissues, and the elongating joints and associated leaves.

2. The nitrogen content of the blades is higher than that of the joints to which they are attached, which in turn is higher than the sheaths.

3. The phosphorus values of the joints are higher than the associated blades and sheaths. The P content of the stalk increases from base to top.

4. The potassium composition of the sheaths is higher than the associated blades. The K values of the upper portion of the stalk are higher than the corresponding leaves. The K content of the stalk increases from base to top.

5. There is a translocation of N, P and K from the older to the younger leaves. The N translocation appears to level out at about the fifth leaf.

6. There is an accumulation of Ca and Mg in the older leaves.

SECTION B

THE RELATION OF COMPOSITION TO AGE

In a discussion of age, it is important to keep in mind that, although the plant grows older with time, the basal internode is the only part of the stalk that is sampled that actually ages. The sampled 8–10 internodes, the leaf sheaths and the leaves represent tissues of approximately the same maturity, irrespective of the time of sampling. The variations in composition of the latter tissues with time reflect changes that have been taking place in the older parts of the plant, or seasonal differences perhaps. Moreover, between the 10 to 15 months of age period, suckers begin to alter the nature of the plant population.

NITROGEN

Changes in the nitrogen composition of the plant with age will depend upon the relative nitrogen levels as determined by 1) location as related to the nitrogen status of the soil, 2) the tissue that is being sampled, 3) the nitrogen fertilization, and 4) the time of planting.

Nitrogen Levels as Affected by Location

The major effects of location and the composition behavior of unfertilized plots are shown in Table 1, Figures 4 and 5, and Figures 1A to 6A in Appendix A. They are:

1. The nitrogen content of the unfertilized plants at six months of age is higher at Kekaha and Olaa than at Grove Farm, Lihue, Oahu, Pioneer and Olokele (eight months), even though the latter did receive 44 pounds of N at planting. This is due to the higher organic matter content of the Kekaha and Olaa soils.

2. The total nitrogen of the basal (BTN) and 8–10 (8–10N) internodes from unfertilized plots does not change appreciably with the age of the crop. There is a general tendency for the BTN to approach 0.1 per cent at harvest, irrespective of the original levels.

3. Leaf nitrogen (LN) levels of unfertilized plants exhibit high nitrogen contents at six months of age. LN values show wider fluctuations with age than either BTN or 8–10 N.

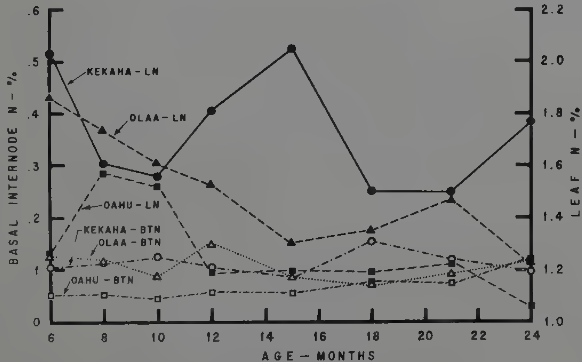


Figure 4. Nitrogen levels as affected by location.

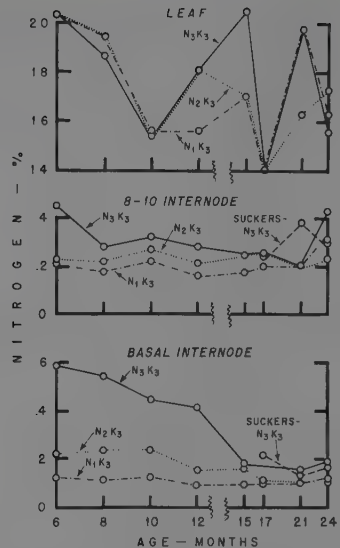


Figure 5. The effect of age on N levels as related to fertilization and tissues analyzed. Kekaha Sugar Co.

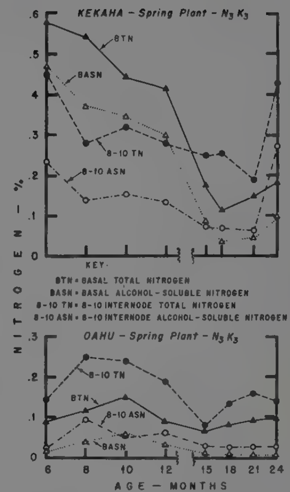


Figure 6. The relation of alcohol-soluble N to total N as affected by age.

TABLE 1. COMPOSITION OF UNFERTILIZED PLOTS AT 8 MONTHS

Plantation		Basal Internode Spring	Fall	8–10 Internode Spring	Fall	Leaf or Leaf Sheath Spring	Fall	Soil* Spring	Fall
		%	%	%	%	%	%	lbs./A	lbs./A
Kekaha	N	0.112	0.114	0.167	0.170	1.61	1.73	—	—
	K	0.16	0.11	0.93	1.03	2.12	2.37	320	—
	P	0.123	0.08	0.115	0.115	0.08	0.08	173	—
	H_2O	77.4	70.9	83.3	83.4	81.6	79.5	—	—
Grove Farm	N	0.059	0.069	0.113	0.116	1.64	1.52	—	—
	K	0.08	0.05	0.71	0.18	1.90	1.13	190	160
	P	0.056	0.028	0.077	0.043	0.12	0.10	92	52
	H_2O	73.2	72.8	81.8	81.3	80.5	78.6	—	—
Lihue	N	0.067	0.073	0.112	0.120	1.56	1.40	—	—
	K	0.10	0.05	0.75	0.08	2.06	1.25	225	160
	P	0.039	0.024	0.053	0.040	0.10	0.08	44	125
	H_2O	72.0	72.2	81.3	81.8	81.0	76.9	—	—
Oahu	N	0.053	0.130	0.133	0.234	1.57	1.83	—	—
	K	0.53	0.15	2.04	1.04	3.26	2.48	550	360
	P	0.113	0.055	0.150	0.108	—	—	120	60
	H_2O	73.6	73.4	84.4	84.8	83.9	83.2	—	—
Pioneer	N	0.059	0.090	0.099	0.118	1.63	1.36	—	—
	K	0.07	0.04	0.82	0.37	1.94	1.52	320	160
	P	0.059	0.105	0.086	0.134	0.12	0.16	190	145
	H_2O	70.6	69.0	78.6	77.4	78.3	78.1	—	—
Olaa	N	0.113	0.991	0.124	0.127	1.74	1.72	—	—
	K	0.12	0.10	0.37	0.55	1.19	1.99	80	162
	P	0.033	0.032	0.048	0.066	0.10	0.10	15	—
	H_2O	71.7	73.8	79.0	81.0	80.0	80.0	—	—
Olokele	N	0.112	—	0.126	—	1.50	—	—	—
	K	0.04	—	0.47	—	1.64	—	360	—
	P	0.049	—	0.065	—	0.10	—	80	—
	H_2O	70.4	—	80.0	—	86.1	—	—	—

*Samples taken prior to planting.

Nitrogen Levels as Affected by Fertilization

The salient effects of fertilization on nitrogen composition are illustrated in data in Figures 5 and 6 and 1A to 6A in Appendix A. They may be summarized as follows:

1. The BTN and 8–10 N contents of the plant were always increased by additions of nitrogen fertilizers.

2. Nitrogen fertilization did not always result in an increase in the LN of the plant. At Kekaha (Figure 5), where the last N was applied at 4.8 months, the leaf did not change composition irrespective of fertilization. At Grove Farm (Figure 1A), where the last N was applied at five months, there was no distinguishable difference between 150 and 300 pounds N. At Olaa (Figure 5A), where the last N was applied at 3.8 months, only the 300-pound application gave higher LN during the six to 10-month period. At Oahu (Figure 3A), where the last N was applied at 6.4 months, the LN for 150 pounds N was higher than for 300 pounds until after eight months of age, after which there was little difference. Lihue (Figure 2A) shows a good, consistent increase in LN with nitrogen fertilization. Olokele (Figure 6A), where the last N was applied at four months, exhibited a pronounced increase in N composition with fertilization at five months, but only the 300-pound application maintained this higher value after eight months.

3. There is a rather consistent downward trend of BTN and 8–10 N with age, giving a typical nitrogen-decay curve.

4. Although the nitrogen-decay curve is experienced with LN, the variations in composition with time are more widely fluctuating than in the case of stalk nitrogen.

5. At high nitrogen levels, BTN values are larger in the early growth of the crop than the 8–10 N (Kekaha, Figure 6); when nitrogen is on the deficiency side, the 8–10 N exceeds the BTN (Oahu, Figure 6).

6. The curves in Figure 6 show that the alcohol-soluble and total-nitrogen curves parallel each other throughout the life of the crop.

7. The nitrogen content of the suckers is quite similar to that of the primaries.

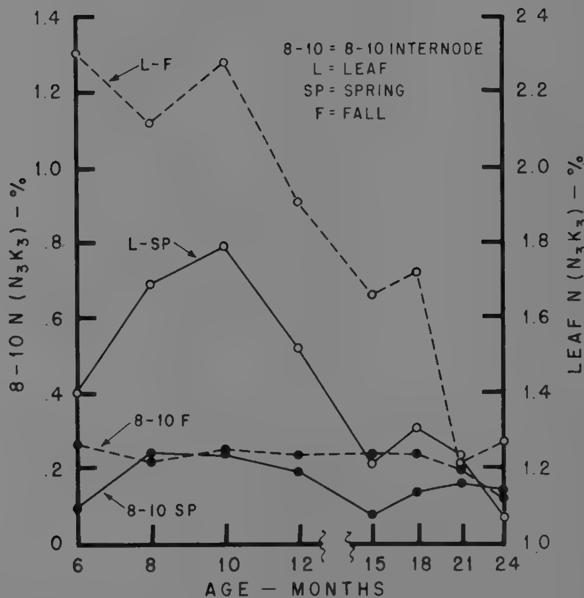


Figure 7. The relation of N composition changes with age to time of plant. Oahu Sugar Co.

Nitrogen Levels as Affected by Time of Plant

The effect of time of plant upon nitrogen composition is shown in Figures 7 and 7A to 11A in Appendix A, and may be summarized as follows:

1. There is a wide variation between plantations with respect to differences in nitrogen composition as related to spring and fall plant crops. At Oahu (Figure 7) and Kekaha (Figure 7A); the fall plant has a higher 8–10 N content at six months of age with the same fertilization than the spring plant. This difference disappeared at eight months of age. Grove Farm (Figure 8A), Lihue (Figure 9A), Pioneer (Figure 10A), and Olaa (Figure 11A) exhibit only slight differences.

2. The fall N was higher than the spring N throughout the life of the crop only in the 8–10 internodes at Pioneer and Olaa. Even here the differences were not great.

3. The leaf N shows greater variation with time of plant than the 8–10 N. This is particularly evident in Figures 7, 7A and 8A. Leaf N changes seem more susceptible to climatic variations.

4. The lack of any consistent tendency in composition values as related to time of plant calls attention to the fact that the establishment of critical levels is fraught with many hazards.

Nitrogen Composition of Suckers

Suckers enter into the population of the cane field during the second season. The natural question arises as to the relation of their composition to that of the primaries. The data in Figures 5, 1A, 2A and 4A show that, in general, the stalk nitrogen composition of the suckers is quite similar to that of the primaries. These curves are typical of all the results obtained in this comprehensive experiment. Occasionally there is some difference as shown in Figure 2A with the 8–10 internodes at Lihue. The composition of suckers has little practical value as far as aiding in establishing fertilization guides but is important in determining juice quality at harvest.

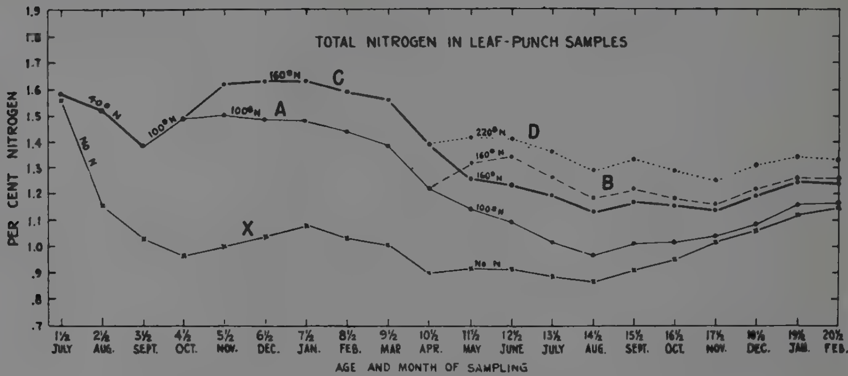


Figure 8. The effect of split applications on the behavior of leaf N with age (after Borden, Haw. Planters' Record 48:287, 1944).
Yield (20½ mos.): A=13.54; B=16.14; C=16.49; D=17.05; X=7.70.

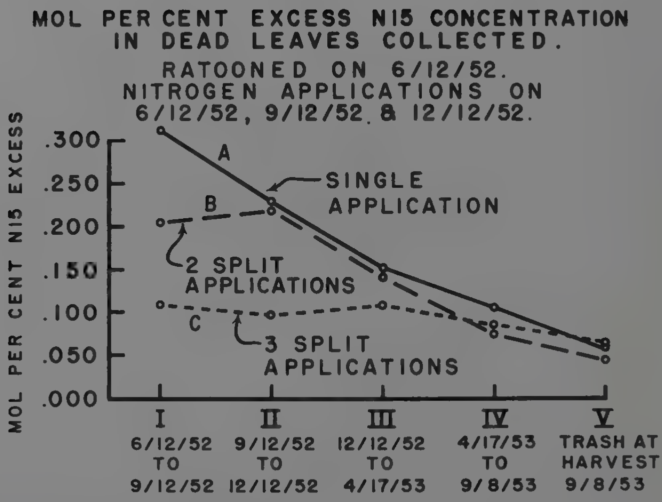


Figure 9. The effect of split applications on the N15 concentration of leaves (after Burr and Takahashi, Haw. Planters' Record, 55:8, 1955).

Relations Between Time of Application of N and Plant Composition

In the previous graphs, all fertilization took place in three applications, ranging from with the seed to six months of age. Plant composition values represented samples taken from one to three months after the last application of fertilizer. The data in Figures 8 and 9 show trends of plant composition as related to time of application. In Figure 8, 40 pounds of N were added at one and one-half months of age and additional 60-pound applications were made at three and one-half, four and one-half and 10½ months. In Figure 9, additions of heavy nitrogen (N15,) were made 1) all at ratooning time, 2) split in two doses, at ratooning and at three months of age, and 3) split in three doses, at ratooning, at three months and at six months. The results from these two independent experiments justify the following conclusions:

1. The N composition of the plant at any given age in the first season of growth depends upon the method of fertilization.

2. The N composition at harvest approaches the same values except when comparing late applications of higher amounts of nitrogen with lower amounts. (Compare Curves A and B, B and C, and B and D in Figure 8 as well as all three curves in Figure 9.)

3. There is no standard level of N for the first season in relation to yield at harvest. This is illustrated in Curves B and C of Figure 8. The higher level in Curve C during the first season and a lower level during the second yielded as much sugar as Curve B when the N value was raised by second season fertilization.

4. The N15 data illustrate clearly that split applications of N eventually bring the N composition curves to the more or less normal N-decay curve for a single application. In this respect, the refined measurements of Burr and Takahashi, using modern techniques, confirm the field work of Borden carried out 11 years previously.

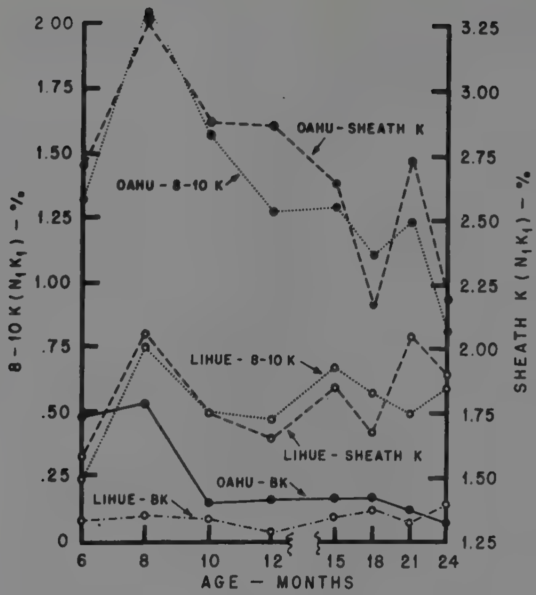


Figure 10. Plant potassium levels as affected by location.

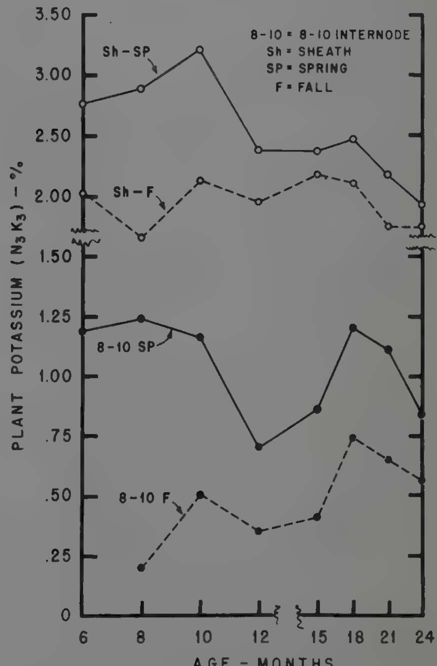


Figure 11. The relation of plant potassium values to time of planting. Pioneer Mill Co.

POTASSIUM

The data in Table 1 and Figure 10 bring out the following pertinent facts between location and the K composition of the cane:

1. The available potash in the soils varies between 80 pounds per acre at Olaa to a high of 485 and 550 pounds at Kekaha and Oahu, respectively.

2. The K content of the unfertilized plant reflects the available potash content of the soil. This is clearly indicated in Figures 10 and 23 in Section C. It is significant to note that even on a high potash soil, such as Oahu, the composition of the basal internode of unfertilized plants approaches that of the low potash soil after 10 months of age. This is not so true for the 8–10 internodes or the sheath, although the Oahu K values decrease with age while the Lihue values remain about constant.

3. There is a very close correlation between 8–10 K and sheath K. This will be discussed further in Section C (see Figure 24). The accidental choice of ordinate values in order to get the sheath-K values on the same graph as stalk K brings out this correlation rather effectively.

4. The basal internode is rather insensitive to K changes with time.

Potassium Levels as Affected by Fertilization

Time of plant had less effect upon composition than the available potash of the soil at the site of the experiment (Figures 11 and 17A to 21A). This is illustrated in Figure 11 at Pioneer where the K values for the fall plant are considerably lower than those for the spring, due to a higher available soil potassium content at the site of the spring planting.

Unlike nitrogen, the K composition of suckers is considerably higher than that of the primaries. This fact, shown in Figures 12 and 13A, emphasizes the necessity for exercising care in the sampling of a population of stalks in the field.

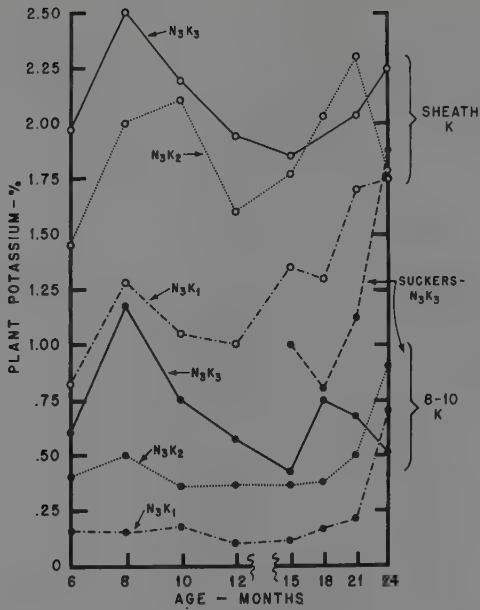


Figure 12. Plant potassium levels as affected by fertilization and age of crop—spring plant. Lihue Plantation Co.

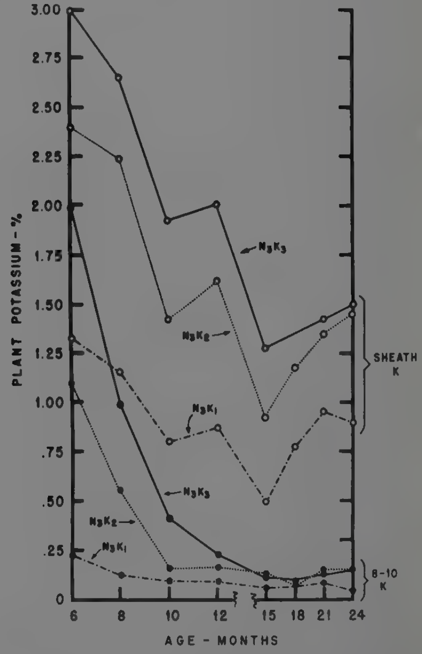


Figure 13. Plant potassium levels as affected by fertilization and age of crop—spring plant. Olaa (Puna) Sugar Co.

The curves in Figures 10, 12 and 13, along with Figures 12A to 16A in Appendix A, justify the following conclusions regarding the effect of potash fertilization upon plant K:

1. Irrespective of the nature of the tissues analyzed, potash fertilization increased the K composition of the plant and tended to level out the composition values with time.

2. With the exception of Olaa (Figure 13), there was no general gradual decrease in K composition with time as in the case of nitrogen. At Kekaha (Figure 12A), both sheath K and 8–10 K increased with age. At Oahu (Figure 14A) and Pioneer (Figure 15A), plant K in the later life of the crop was nearly the same as in the earlier months with a drop in composition at 12 to 15 months of age. This is interesting in light of the fact that the available soil potassium was high at both sites. At Lihue (Figure 12), Grove Farm (Figure 13A) and Olokele (Figure 16A), there was considerable fluctuation with age, but the average composition was approximately the same throughout the life of the crop.

3. Composition values at Olaa (Figure 13) tell a different story. Here we see gradual decreases in the content of both sheath K and 8–10 K with age, similar to the usual experience with plant N. Apparently, on this shallow, acid, low-potash soil, the early applications of potash (by 3.8 months) were not sufficient to maintain satisfactory potassium levels in the plant after eight months of age. This suggests the possibility of some K losses by leaching.

4. The 8–10 K and sheath K for the N_3K_1 treatment increased with age, with the exception of Olaa.

5. The K composition of the plants for all potash treatments approached a common level at harvest.

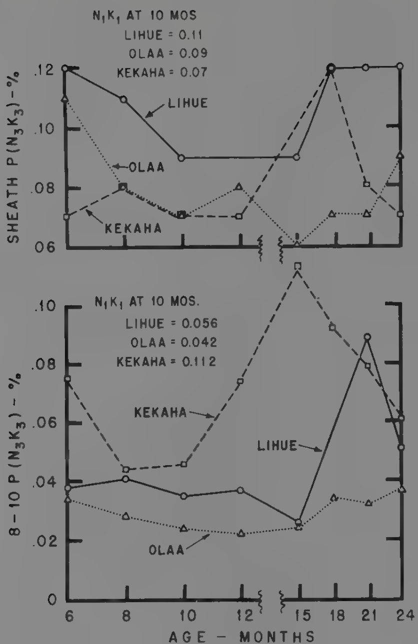


Figure 14. The relation of changes in the P composition of cane tissues to age.

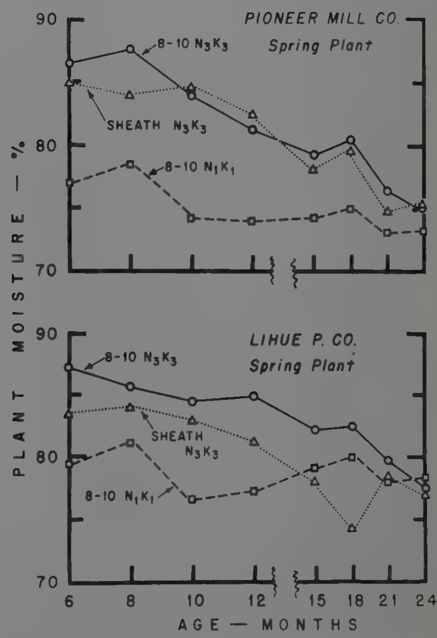


Figure 15. The effect of fertilization and age upon the moisture content of cane tissues.

PHOSPHORUS

The graphical data in Figures 14 and 22A point out the following facts regarding changes in the phosphorus composition of the plant with age:

1. By comparing the phosphorus composition at 10 months of age of the N_1K_1 (unfertilized) and N_3K_3 plots, it is obvious that fertilization lowered the P levels of the plant tissues. It will be shown in Section D that this effect is due to nitrogen.

2. The graphs indicate a tendency for a lowering of the P levels in the plant tissue during the period of 10 to 15 months of age. This is more pronounced on the soils containing higher amounts of available phosphorus (Kekaha, Oahu and Pioneer).

3. The P levels of the 8–10 internodes reflect the available soil P. The sheath P values have little to no relationship to the phosphorus reserves in the soil. These relationships will be discussed further in Section C.

4. The changes in P levels with age are more similar in character to the K levels than to N variations.

MOISTURE

The curves in Figure 15 are typical of other plantations and warrant the following conclusions:

1. Moisture changes with age follow a rather uniform pattern, irrespective of location, fertilization and time of plant. There is a gradual decrease in moisture content with age for all tissues analyzed.

2. The 8–10 M and sheath M values parallel each other at the various ages.

3. Fertilization with nitrogen and potash raises the moisture levels, especially in the early life of the crop. It will be shown in Section C that this is highly correlated with N composition.

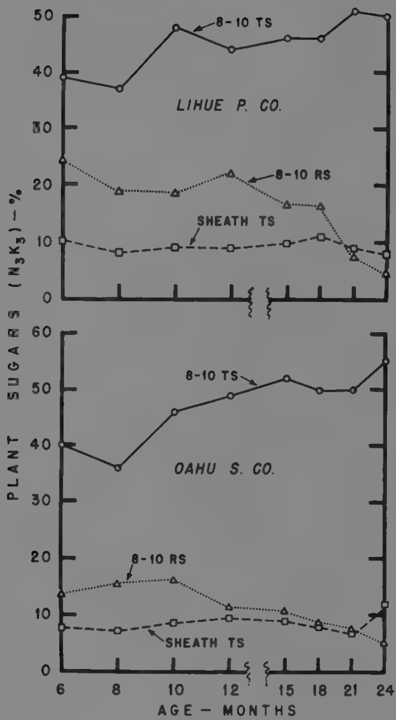


Figure 16. The effect of age upon changes in the total and reducing sugars in cane tissues.

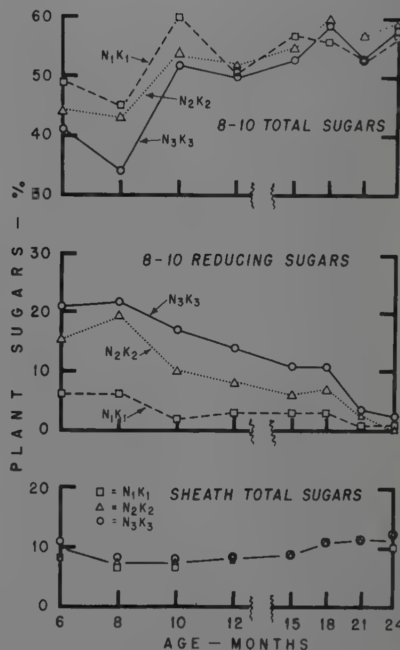


Figure 17. The effects of fertilization and age upon levels of total and reducing sugars—Pioneer Mill Co.

SUGAR

Total sugars (TS) were determined upon both leaf sheath and stalk tissues. Reducing sugars (RS) were measured only in the stalk tissues. The graphs in Figures 16 and 17, along with 23A to 25A in Appendix A, point out the following significant facts with respect to changes in the sugar content of the plant with age:

1. As should be expected, the TS in the 8–10 internodes, which are storage tissues, are about four to five times the amount in the leaf sheath.

2. There is a general increase in the 8–10 TS with age, but only a slight variation in sheath TS. The 8–10 RS decrease with age, especially during the last six months.

3. As shown in Figures 17 and 24A, fertilization has more effect upon the RS values than on the TS. Sheath TS do not exhibit appreciable changes from fertilization. In Figure 17, for example, the yields of sugar varied from 5.0 to 14.3 tons per acre as a result of fertilization with no significant changes in the TS values of the sheath. The 8–10 RS exhibited the effect of the fertilizer treatments.

SECTION C

INTERRELATIONSHIPS BETWEEN VARIOUS COMPOSITION FACTORS

Data were obtained to ascertain the advantages, if any, of using the unassimilated, or alcohol-soluble, nitrogen as an index of the N composition of the plant. Comparisons were made of basal internode N with 8–10 N, as well as between leaf N and stalk N. The results will be discussed in this section along with the impact of N composition on reducing sugars.

Alcohol-soluble-Total Nitrogen Relationship

The curves in Figures 6 and 18 permit the following generalizations:

1. Confirming the parallel nature of the alcohol-soluble (BASN)-total nitrogen (BTN) curves in Figure 6, there is an exceedingly close correlation between these two types of nitrogen, as should be expected. The correlation coefficient is 0.9944.

2. Due to the mechanical problems associated with obtaining field samples for alcohol-soluble determinations, and the high correlation between total N and alcohol-soluble N, it is obvious that total nitrogen is the more feasible for practical use.

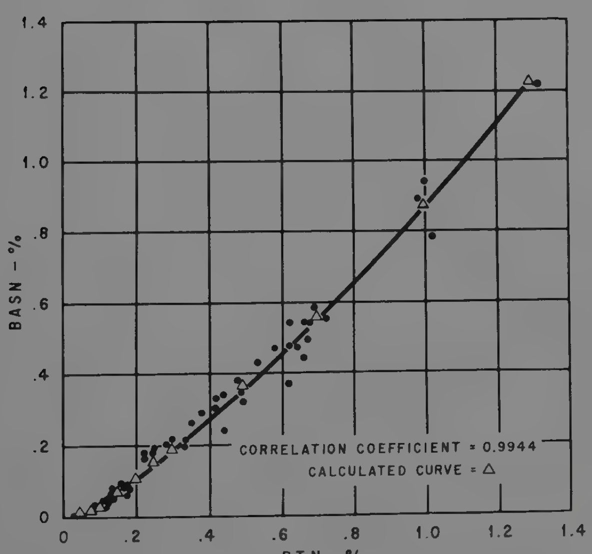


Figure 18. The relation of alcohol-soluble to total nitrogen.

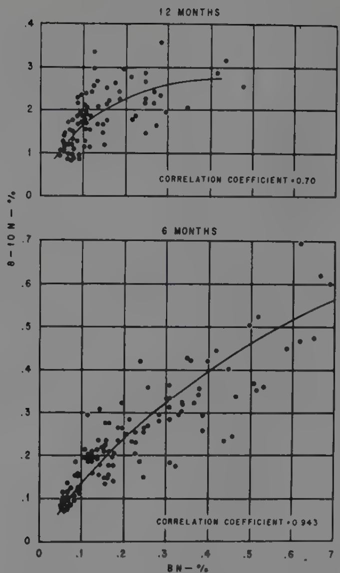


Figure 19. The relation between basal N and 8–10 N.

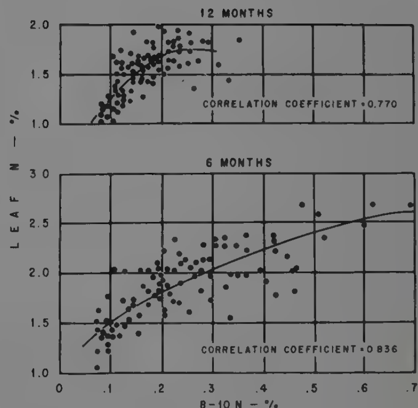


Figure 20. The relation between 8–10 N and leaf N.

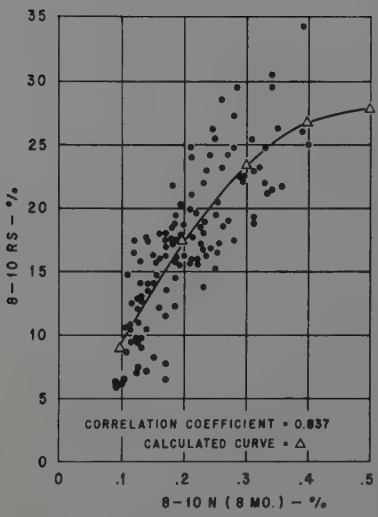


Figure 21. The relation of 8-10 RS to 8–10 N.

Relation between Basal Nitrogen and 8–10 Nitrogen

An analysis of Figures 5, 19 and 1A to 6A in Appendix A brings out the following important relationships between 8–10 and basal nitrogen values:

1. There is a very close correlation between 8–10 N and BN, as should be expected from the fact that they are both stalk tissues. The correlation at six months of age is much better than at 12 months.

2. At high levels of nitrogen, BN is higher than 8–10 N at six months of age. As the age of the crop increases, the BN of plants from these same treatments decreases more rapidly than the 8–10 N until the latter is higher than the basal tissues. This indicates the translocation upward of nitrogen as the crop develops.

3. The translocation of N upwards in the stalk with age helps to explain the poorer correlation value at 12 months.

Relation between 8–10 Nitrogen and Leaf Nitrogen

The following generalizations can be made from Figures 5, 20 and 1A to 6A in Appendix A relative to the correlation between 8–10 N and leaf N:

1. In spite of the wide fluctuations of LN with age, as shown in Figures 5 and 1A to 6A, there is a fairly good correlation between 8–10 N and LN. This correlation is higher at six months of age than at 12.

2. At low nitrogen levels, the LN values are 10 to 15 times those of 8–10 N. At high nitrogen levels, this differential is cut approximately in half.

Relation of 8–10 Reducing Sugars to 8–10 Nitrogen

The data contained in Figures 17, 21 and 24A bring out the following points relative to the relations of reducing sugars to nitrogen:

1. Nitrogen fertilization increases the reducing sugar composition of the cane plant. This is illustrated in Figures 17 and 24A.

2. As shown in Figure 21, there is a very satisfactory correlation between 8–10 N and 8–10 RS. This is a basic plant physiological relationship and such a correlation should be expected.

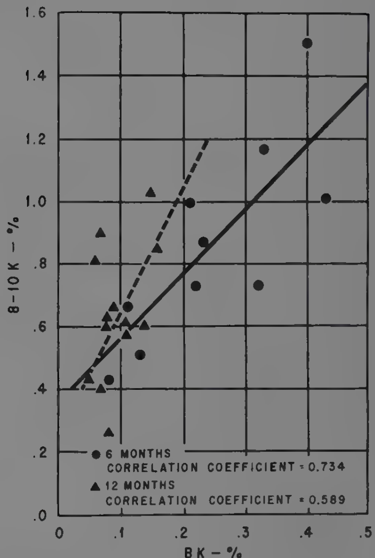


Figure 22. The relation between basal K and 8–10 K.

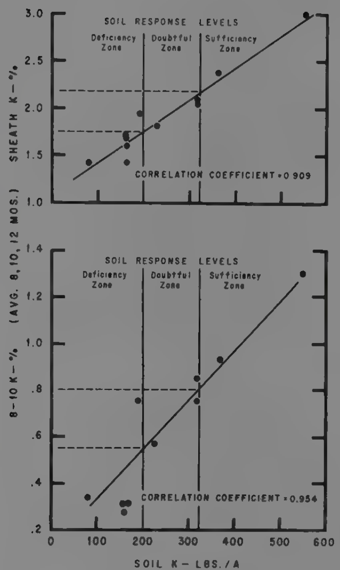


Figure 23. The relation of plant K to soil K.

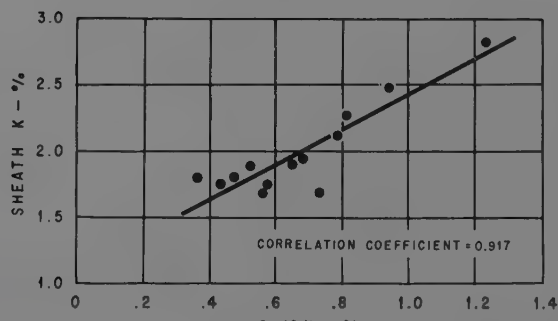


Figure 24. The relation between 8–10 K and sheath K.

POTASSIUM INTERRELATIONSHIPS

The important interrelationships involving potassium include those comparing the K values of (1) the basal and 8–10 internodes, (2) the 8–10 internodes and sheath, and (3) the plant versus available soil potassium. Inasmuch as the curves showing the changes of plant K with the age of the crop indicated no systematic trend as the crop grew older, but did show possible luxury consumption at six months in a few cases, the K values used are the averages for 8, 10 and 12 months, except where noted. The available soil potassium from the unfertilized plots was determined by the method reported by Ayres and Hagihara (Hawaiian Planters' Record, 55:113, 1955).

The Relation between 8–10 Potassium and Basal and Sheath Potassium

The data in Figures 22 and 24 show the following significant points concerning the interrelationships existing between the K composition of different cane tissues:

1. The basal K values are much lower than the corresponding 8–10 K amounts.
2. The difference between BK and 8–10 K increases with age as potassium is translocated from the lower to the upper part of the plant. The correlation coefficient between BK and 8–10 K is 0.734 at six months and 0.589 at 12 months of age.
3. The sheath K values are considerably higher than the corresponding 8–10 K amounts.
4. The data in Figure 24 confirm those presented previously in Figure 10 and establish a high correlation between 8–10 K and sheath K. The correlation coefficient is 0.917.

The Relation of Plant Potassium to Available Soil Potassium

The data in Figure 23 show the relationship between available soil K and both 8–10 K and sheath K. The following conclusions are warranted from these results:

1. There is a very high degree of correlation between both 8–10 K and sheath K and the available soil potassium. The correlation coefficient for soil K: 8–10 K is 0.954 and for soil K: sheath K is 0.909.
2. These high correlations make the available soil K an important part of the soil-plant analyses picture for establishing fertilizer recommendations. This will be discussed more thoroughly in Sections G and H.

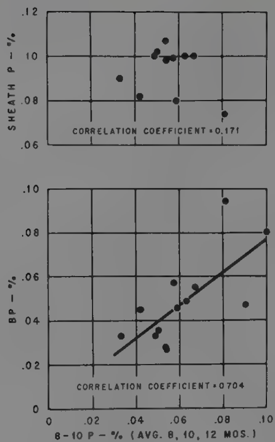


Figure 25. The relation between 8–10 P and basal P and sheath P.

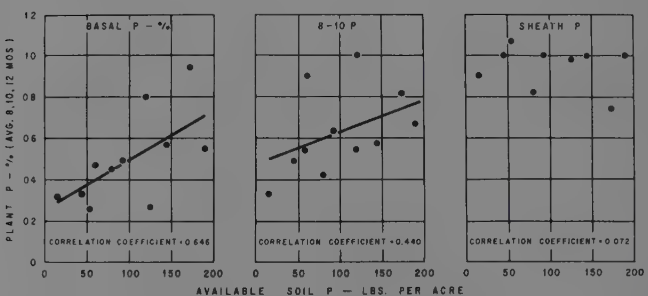


Figure 26. The relation of plant P to available soil P.

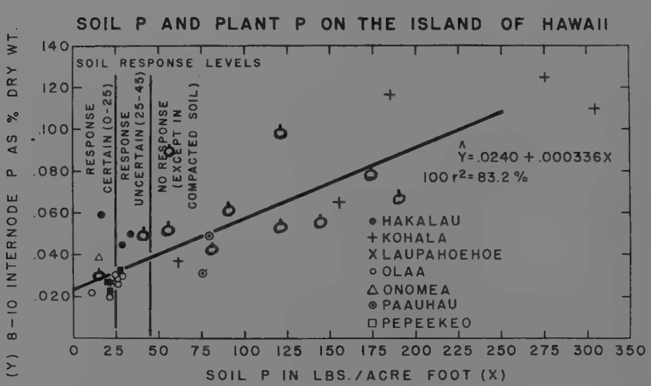


Figure 27. The relation of 8–10 P to available soil P. (after Hartt, Haw. Planters' Record, 55:267, 1958). ȯ represents the P values obtained in this study.

PHOSPHORUS INTERRELATIONSHIPS

The three significant phosphorus interrelationships include comparisons of (1) basal P with 8–10 P, (2) 8–10 P with sheath P, and (3) available soil P with plant P. The P values used for the plant tissues consist of the averages of all composition determinations for 8, 10 and 12 months of age. All plots received a uniform application of 200 pounds of P_2O_5 per acre at planting time. The available soil phosphorus from samples taken prior to fertilization was determined by the method reported by Ayres and Hagihara (l.c.).

The Relation between 8–10 Phosphorus and Basal and Sheath Phosphorus

The data in Figure 25 permit the following generalizations concerning the P correlations involving both stalk and sheath tissues:

1. There is a fairly close relationship between basal P and 8–10 P. The correlation coefficient is 0.704. The 8–10 P is only slightly higher than basal P, indicating less translocation within the plant than nitrogen and potassium.

2. There is a very poor correlation between 8–10 P and sheath P. The correlation coefficient is only 0.171. These data confirm numerous observations that the sheath P is not a satisfactory index of the P needs of the plant.

The Relation of Plant Phosphorus to Soil Phosphorus

The results in Figures 26 and 27 point out the following significant facts concerning the relationship of plant P values to the amount of available soil P:

1. The correlation between available soil P and basal P is superior to that of the soil P: 8–10 P relationship. Two points out of the 11 locations are responsible for decreasing the magnitude of the correlation between stalk P and available soil P. There is a complete lack of correlation between available soil P and sheath P.

2. The available soil P results from this study when transposed on the graph (Figure 27) originally produced by Hartt (l.c.), confirm the reliability of the soil P: 8–10 P correlation. Only two points previously referred to are significantly off the calculated line.

3. The results in Figures 26 and 27 emphasize the important significance of available soil P values for establishing fertilizer recommendations. This will be discussed further in Section H.

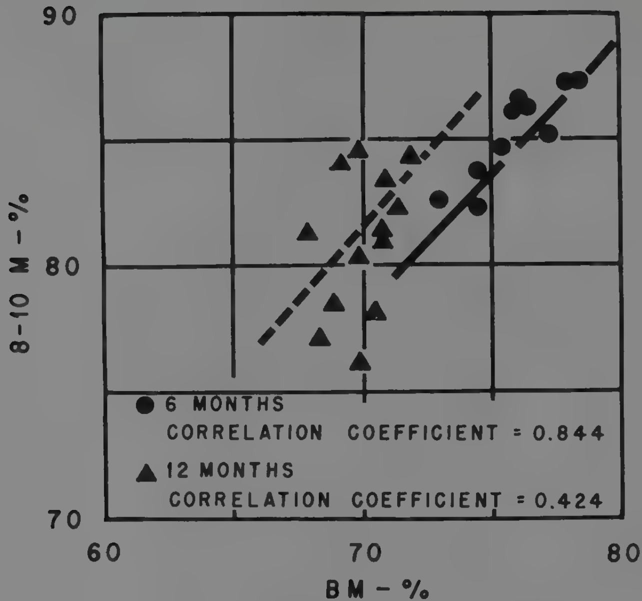


Figure 28. The relation between basal M and 8–10 M.

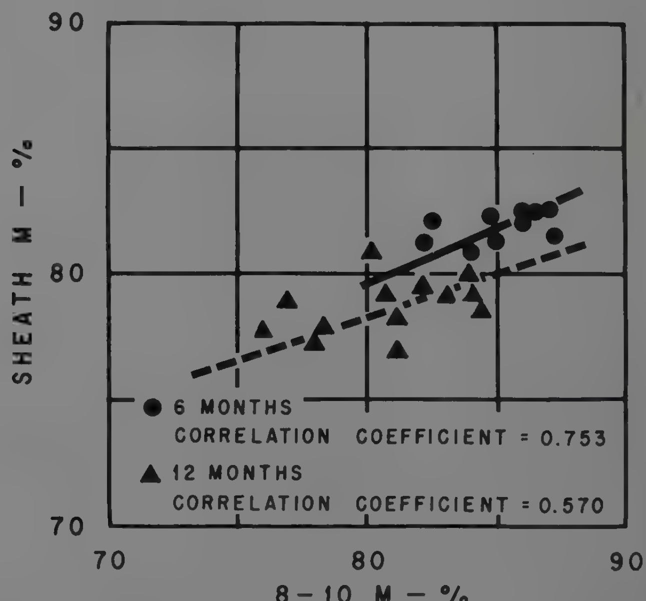


Figure 29. The relation between 8–10 M and sheath M.

MOISTURE INTERRELATIONSHIPS

The important aspects of plant moisture interrelationships include (1) comparisons of 8–10 moisture with both basal and sheath moisture, (2) the correlation of plant moisture with both plant N and reducing sugars, and (3) the lack of correlation between plant K and plant moisture.

The Relation between 8–10 Moisture and Basal and Sheath Moisture

The data in Figures 28 and 29 summarize the relationships between the moisture content of stalk and sheath tissues rather clearly as follows:

1. There is a good correlation between BM and 8–10 M in the early stages of growth; the correlation coefficient is 0.844 at six months of age. This coefficient decreases to 0.424 at 12 months as the basal internode matures.

2. The correlation between 8–10 M and sheath M is fairly good at six months of age, giving a correlation coefficient of 0.753. This coefficient decreases to 0.570 at 12 months. At six months, the average 8–10 M values range between about 82½ to 87 per cent; the sheath M varies only between about 81 and 83 per cent. At 12 months, the average 8–10 M values range between about 75½ and 84½ per cent, while the sheath M ranges between about 77½ and 81 per cent.

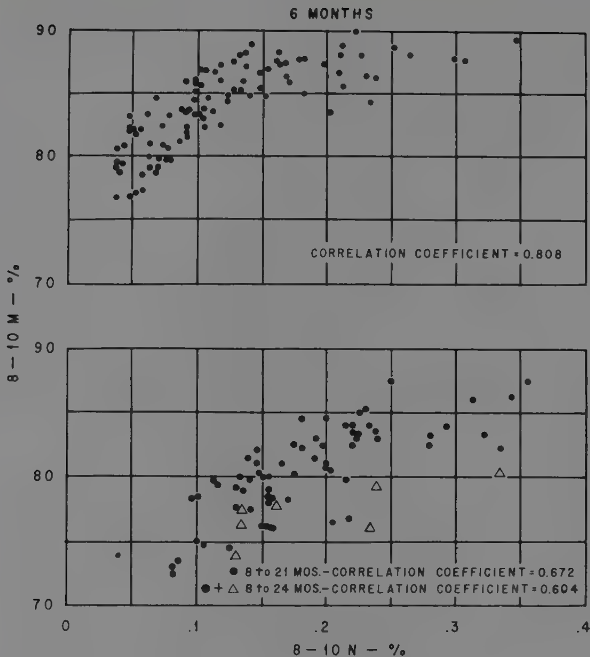


Figure 30. The relation of 8–10 M to 8–10 N.

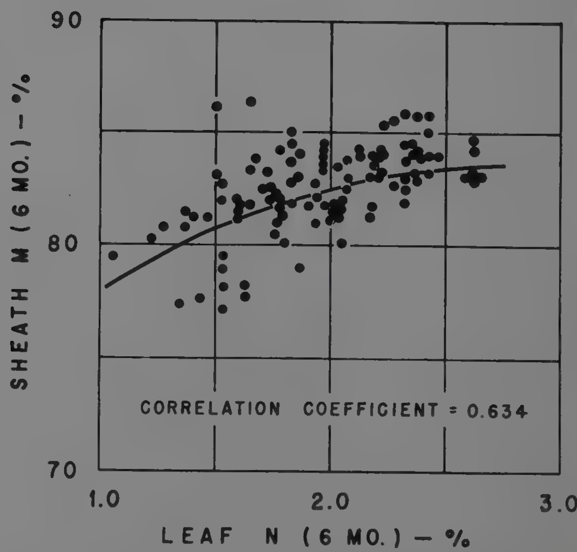


Figure 31. The relation of sheath M to leaf N.

The Relation of Plant Moisture to Plant Nitrogen

The fact has been well established that the moisture content of the plant is highly correlated with the nitrogen composition of the leaf (Exp. Sta. HSPA Releases 56, 88, 125, Haw. Agr. Exp. Sta. Tech. Bul. 18). It has been shown that 8–10 N and 8–10 moisture composition of the cane plant decrease similarly with age (Figure 15). The results in Figures 30 and 31 show the correlation between plant N and plant M with samples taken at six months of age and permit the following generalizations:

1. The correlation between 8–10 N and 8–10 M is higher than that between leaf N and sheath M. The correlation coefficient for the stalk tissues was 0.808; that for the leaf and sheath tissues was 0.634.

2. The correlation between 8–10 N and 8–10 M decreases with age. If one takes all treatments, all plantations and all ages, the following coefficients are obtained:

8–10 M vs 8–10 N for 24 months = 0.604

8–10 M vs 8–10 N except 24 months = 0.672

The reason for the lower correlation of 24 months when compared with 21 is due to the drying off of the former prior to harvesting.

3. The moisture content of the 8–10 tissues is generally higher than that of the leaf sheath. The maximum for 8–10 M approaches 90 per cent; that for the leaf sheath is about 85.

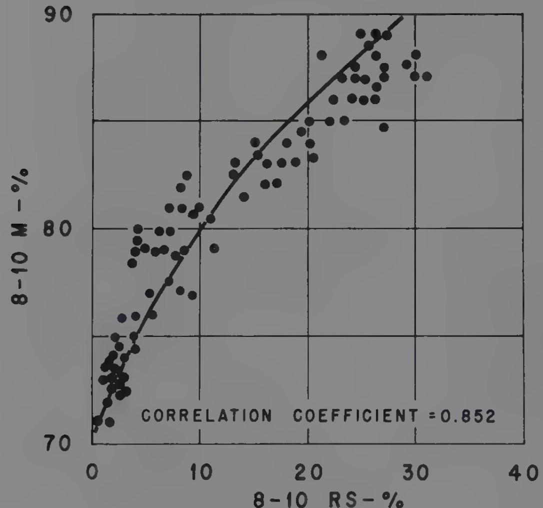


Figure 32. The relation of 8–10 M to 8–10 RS.

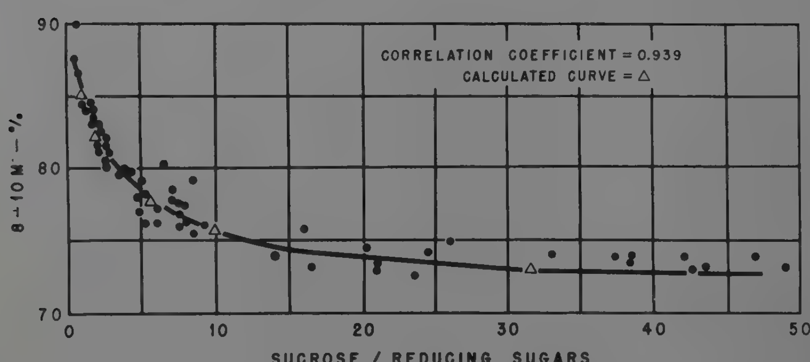


Figure 33. The relation of 8–10 M to the sucrose-reducing sugar ratio.

The Relation of 8–10 Moisture to Reducing Sugars

The data in Figure 21 show that there is a high correlation between 8–10 N and 8–10 RS. It is also shown in Figure 30 that there is a high correlation between 8–10 N and 8–10 M. One should then expect a close relationship between 8–10 M and 8–10 RS. The curves in Figures 32 and 33 verify this reasoning and permit the following conclusions:

1. The correlation between 8–10 RS and 8–10 M is much higher than that between 8–10 N and 8–10 M. The curve in Figure 32 represents points from all treatments and ages at seven plantations. When one compares the correlation coefficient of 0.852 for 8–10 RS vs. 8–10 M with the coefficient of 0.604 for 8–10 N vs. 8–10 M for the same plots, the significance of the reducing sugar effect becomes obvious.

2. The correlation coefficient of 0.939 between 8–10 M and the 8–10 sucrose-reducing sugar ratio, shown in Figure 33, is the highest obtained between any other plant composition factor and plant moisture. These data include samples from six to 24 months of age. They point out that under the conditions of early fertilization, an 8–10 M of from 74 to 75 per cent at harvest assures a good sucrose-reducing sugar ratio.

3. In analyzing the data in Figures 21, 30, 32 and 33, one is led to suggest the possibility that the relationship between 8–10 N and 8–10 M is indirect through the impact of nitrogen on the production of reducing sugars.

The Relation of Plant Moisture to Plant K

Statistical analyses of field crop-logging data from Ewa Plantation Co., Hawaiian Commercial and Sugar Co., and Waialua Sugar Co. by Humbert and co-workers (Exp. Sta. Spec. Releases 56, 88 and 125) indicated that the same relationship existed between sheath K and sheath M as between leaf N and sheath M. The data from these experiments, however, do not verify these earlier conclusions. The results in Figure 34, which are typical of other data, along with other statistical correlations, suggest the following conclusions:

1. There is no significant correlation between plant K and plant M. For example, the correlation coefficient between 8–10 K and 8–10 M at six months of age for all plantations and treatments was only 0.146; this coefficient between sheath K and sheath M was only 0.278.

2. Attempts to establish significant correlation values between plant K and plant M at different N levels did not produce positive results.

3. A re-analysis of the field crop-logging data previously mentioned brought to light the fact that there was a rather close correlation between plant N and plant K. Consequently, one should expect a correlation between plant K and plant M, if plant N and plant K are correlated. This fact is illustrated in another manner in Figure 26A in Appendix A. Here it is seen that the change in sheath M with age follows very closely the decline in leaf N. Only between 11 and 16 months is there a correlation between sheath M and sheath K changes. Curves of the same type were obtained with the variety 37–1933.

4. These data should not be interpreted as meaning that the moisture content of the plant will not be affected by those deficiency levels of potassium that seriously restrict growth.

5. These data are not in conflict with the rather general observations, such as on the Hamakua Coast and elsewhere, that a plant well supplied with potassium will withstand drought better than a potassium-deficient one. Under these conditions, the potassium content of the plant decreases as the moisture content is restricted. This is to be expected under dry conditions because of the significance of the root-soil contact in potassium absorption as related to soil moisture.

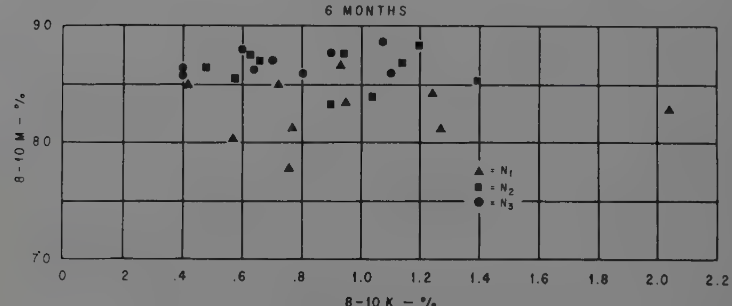


Figure 34. The relation of 8–10 M to 8–10 K.

SECTION D

PLANT COMPOSITION IN RELATION TO FERTILIZATION

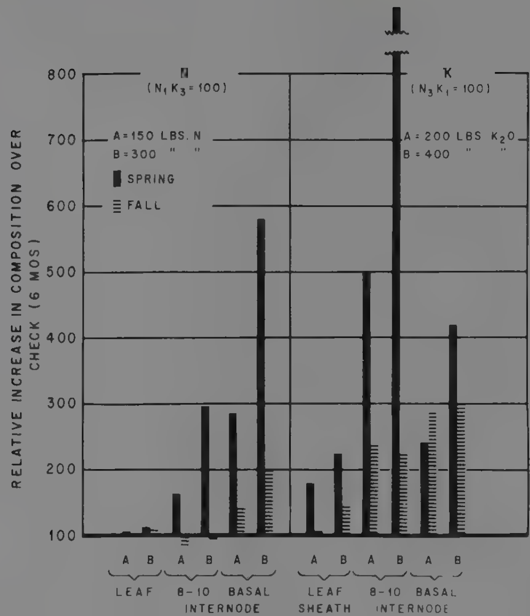


Figure 35. The relative response of cane tissues to N and K_2O fertilization—Olaa (Puna) Sugar Co.

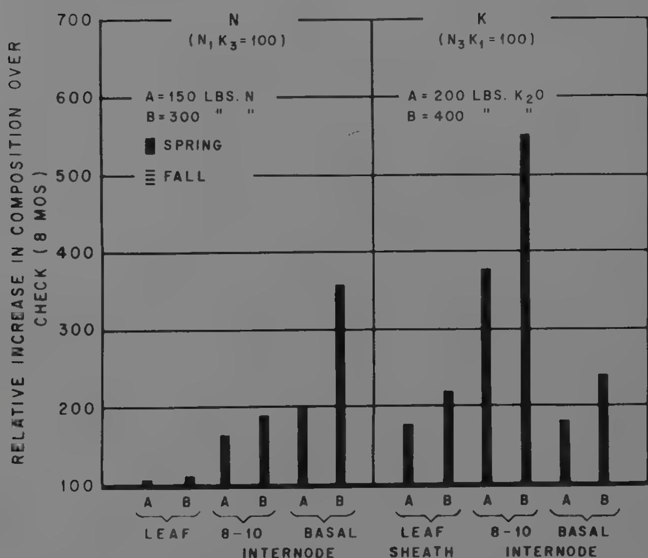


Figure 36. The relative response of cane tissues to N and K_2O fertilization. Olokele Sugar Co.

Effect of Nitrogen and Potash Fertilization upon N and K Composition of Tissues

The bar graphs in Figures 35, 36 and 27A to 31A in Appendix A show the percentage increase over the check (N_1K_3 or $N_3K_1 = 100$ per cent) in the nitrogen and potassium contents of stalk and leaf sheath tissues at six months of age. The N responses were plotted from the 400-pound K_2O treatment; the K responses from the 300-pound N treatment. The following facts are obvious from these data:

1. Nitrogen fertilization had a very small effect upon the percentage increase in leaf N. At Kekaha, Olaa and Olokele, there was only a very slight increase in leaf N over the check with as much as 300 pounds N. At Lihue, Grove Farm, Oahu and Pioneer, 300 pounds N did not increase the nitrogen content over the 150-pound application. The leaf-N reaction to nitrogen fertilization was most pronounced at Oahu where nitrogen levels in the check were very low.

2. Basal N and 8–10 N show a much sharper response to nitrogen fertilization than leaf N. Only in the case of the fall plant at Olaa did the 8–10 N show no increase in fertilization over the check.

3. Basal N is more sensitive to nitrogen fertilization than the 8–10 N.

4. The order of sensitivity to nitrogen fertilization was as follows for the 26 cases involved:

a) BTN >8–10 N or LN	85% of the cases
b) 8–10N >BTN or LN	15% of the cases
c) 8–10N >LN	92% of the cases
d) LN >8–10N	8% of the cases

5. Potash fertilization generally had a rather pronounced effect upon the K composition of the stalk and leaf-sheath tissues. The major exception was Oahu where the available soil potash was high. Even here, the various tissues demonstrated a slight increase in K content. The largest exceptions to this general effect were the sheath K (SK) of the spring plant at Kekaha and the basal K (BK) of the fall crop at Kekaha.

6. The 8–10 K was more sensitive than either the sheath K or basal K. The order of sensitivity for the 26 cases was:

a) 8–10K >SK or BK	73% of the cases
b) BK >8–10 or SK	27% of the cases
c) 8–10K>SK	100% of the cases
d) SK >BK	46% of the cases

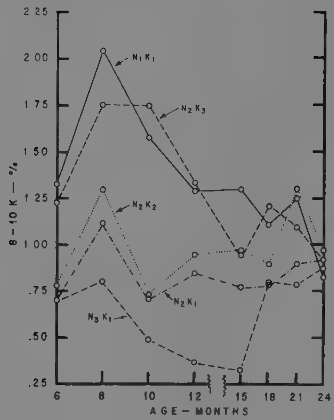


Figure 37. The effect of N fertilization upon 8–10 K levels—Oahu Sugar Co.

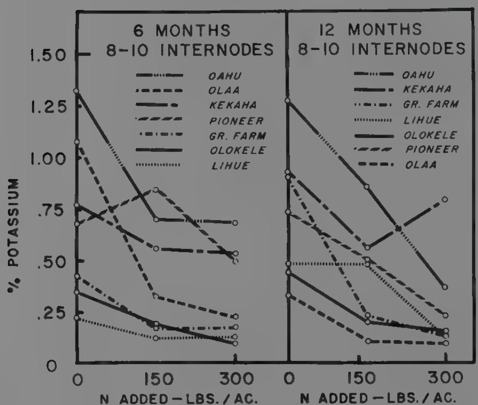


Figure 38. The effect of N fertilization upon 8–10 K levels.

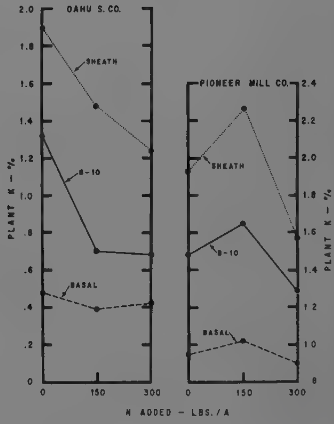


Figure 39. The effect of N fertilization upon K levels of cane tissues.

Effect of Nitrogen Fertilization on the K Composition of the Plant

Nitrogen fertilization has a repressing effect upon the potassium composition of the plant. These effects are shown in Figures 37, 38 and 39. The following points are worthy of note and discussion:

1. The amount of K repression is related to the quantity of nitrogen applied (Figure 37), that is, $N_3K_1 > N_2K_1 > N_1K_1$.
2. About 400 pounds K_2O (N_2K_3) were required to counterbalance the repressive effect of 150 pounds N. This was on a soil where there is no response to potash fertilization.
3. The largest repressive effects are during the first year's growth.
4. The K content of plants growing on soils that have higher amounts of available potash decreases more rapidly with nitrogen fertilization than in the case of plants growing at lower potash levels.
5. The basal K is not appreciably affected by nitrogen fertilization. The sheath K and 8–10 K are greatly affected, in about the same proportion.
6. There is no clear-cut evidence from these experiments to prove that this decrease in K composition results in a decrease in the yield of sugar.
7. It has been demonstrated with a wide variety of crops that the major impact of nitrogen fertilization is to cause rapid growth of the plant. It has been observed that the ratio of top growth to root development increases substantially. These effects would be expected to lead to
    a) a decrease in K composition just as a matter of dilution.
    b) a decrease in K composition due to the inability of the absorbing root surfaces at the soil-root interface to keep pace with the demands of the above-ground portion of the plant. Root-soil contact is very important in the absorption by the root of the nutrients adsorbed on the soil colloidal fraction.

Effect of Nitrogen Fertilization on the P Composition of the Plant

It has been shown previously (Figures 14 and 22A) that nitrogen fertilization represses the phosphorus composition of the plant. Earlier results by Burr and associates (Hawaiian Planters' Record, 55:109, 1955) indicated the same relationship. Such effects are illustrated in Figures 40 and 41. The following pertinent facts may be gleaned from these data:

1. The P content of the plant is decreased by nitrogen fertilization more on those soils that have the highest amount of available phosphorus. This fact parallels the experience of the nitrogen effect on K composition.

2. The repressing effect of nitrogen fertilization on P is confined to the stalk tissues (Figure 41). The sheath is not sensitive enough to phosphorus changes to exhibit any depressing effects.

3. There is no conclusive evidence that this depressing effect of nitrogen fertilization on P composition has a correspondingly harmful effect on the yield of sugar.

4. The explanation of this repressing effect should be the same as that discussed under potassium. Hartt (Hawaiian Planters' Record, 55:258, 1958) has shown that there is a much smaller decrease in the 8–10 P when nitrogen is added in culture solutions than is experienced in the field. This fact lends support to the root-soil contact hypothesis.

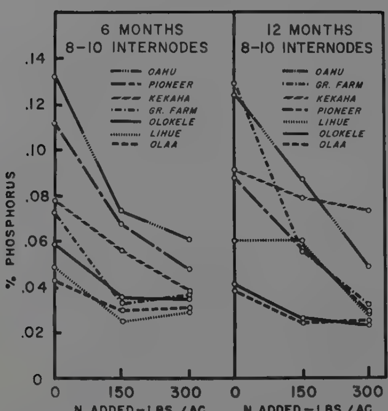


Figure 40. The effect of N fertilization upon 8–10 P levels.

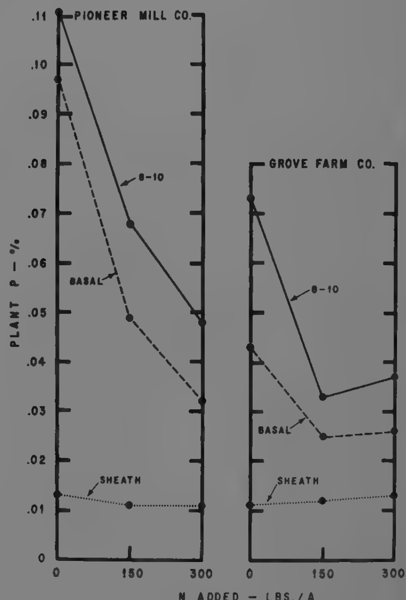


Figure 41. The effect of N fertilization upon P levels of cane tissues.

SECTION E

YIELD IN RELATION TO FERTILIZATION

In discussing the effect of any plant nutrient upon growth, it is important to know its response in relation to other nutrients. This is especially true of nitrogen and potash responses. One should not expect a response from potash fertilization if nitrogen is limiting. One should not anticipate maximal nitrogen response in the absence of adequate potash. The following discussion is based upon an attempt to visualize the significance of nitrogen responses at different levels of potash fertilization and vice versa. The yields are the averages of the 21- and 24-month harvests. A statistical analysis of yield responses from a slightly different approach is presented in Appendix C.

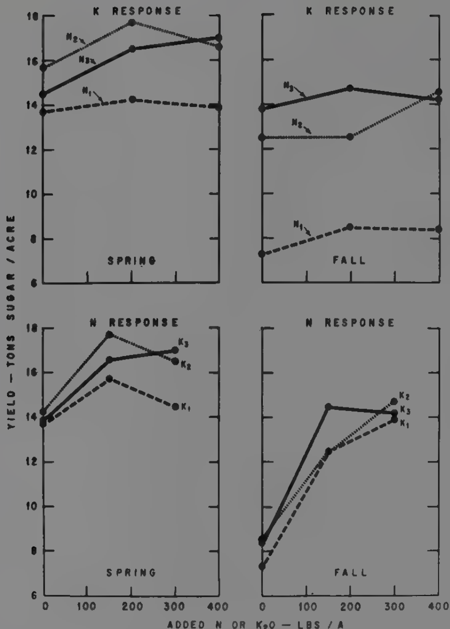


Figure 42. The effect of N and K_2O fertilization upon sugar yields—Kekaha Sugar Co.

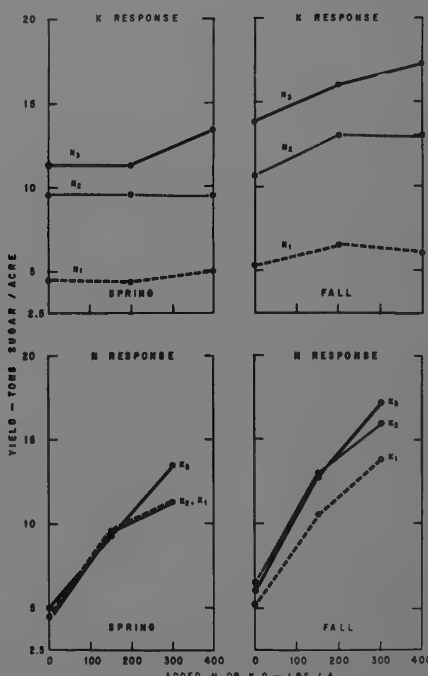


Figure 43. The effect of N and K_2O fertilization upon sugar yields—Pioneer Mill Co.

The Effect of Nitrogen Fertilization on Yield

The responses from the addition of 150 and 300 pounds of nitrogen per acre are shown in the lower half of Figures 42, 43 and 32A to 36A in Appendix A. The yield curves resulting from nitrogen fertilization are shown separately for the three potash levels. The following important facts may be observed from these data:

1. All locations exhibit an increase in yield from at least the first increment of nitrogen fertilization.

2. The first 150 pounds of nitrogen accounts for the major percentage increase in sugar yields. The first increment of nitrogen (150 pounds) was responsible for 77, 70 and 78 per cent of the yields produced by two 150-pound additions of nitrogen at potash levels of 0, 200 and 400 pounds, respectively.

3. The magnitude of the nitrogen response is related to the available soil potassium and the potash fertilizer applied. This is especially marked at Grove Farm (Figure 32A), Lihue (Figure 33A), and Olaa (Figure 35A) where the available soil potassium was low and the response to N depends upon the K_2O fertilization. The average increases in yields of sugar due to nitrogen for the seven plantations for both spring and fall crops were as follows (tons per acre):

	N_2 *over* N_1	N_3 *over* N_1
K_1	3.4	4.4
K_2	3.8	5.4
K_3	4.2	5.4

The Effect of Potash Fertilization on Yield

The responses from the addition of 200 and 400 pounds of potash per acre are shown in the top portion of the same figures discussed under nitrogen. The salient facts from these data are as follows:

1. Response to potash fertilization takes place only on those soils that have insufficient quantities of available potassium in the soil. There was no response at Oahu for either the spring or fall plant and none at Pioneer for the spring plant location (see Figures 34A and 43).

2. Nitrogen fertilization affected the response observed from potash applications. This was particularly true of the first increment of nitrogen (150 pounds). The average increases in yields of sugar due to potash for both the spring and fall crops at Grove Farm, Lihue and Olaa, where the amount of available soil potash is limiting, were as follows (tons per acre):

	K_2 *over* K_1	K_3 *over* K_1
N_1	0.75	1.05
N_2	1.87	2.80
N_3	1.70	2.61

3. If one observes the yield data closely, it is seen that the addition of nitrogen produced a response for the 200-pound application of potash at Kekaha (Figure 42). Also, at Olokele (Figure 36A), there was a potash response when 300 pounds of N had been added.

4. The first increment of potash (200 pounds) was responsible for 71, 67 and 65 per cent of the yields of sugar produced by the two 200-pound additions at nitrogen levels of 0, 150 and 300 pounds, respectively.

5. All of these data point out the necessity of knowing both the available soil potassium and the nitrogen fertilization in evaluating responses from potash fertilizers.

SECTION F

YIELD IN RELATION TO COMPOSITION

It has been shown that nitrogen and potash fertilization increases yields and raises the N and K composition of the plant. It is important to know to what extent composition at any given time can be correlated with yields. It is recognized that yields are affected by many factors other than nutrition, particularly soil differences and the variations in the climatic growth potential of the environment. In order to evaluate the composition factor more accurately, it is necessary to study the composition-yield relationship on an individual plantation basis.

The composition values at eight months of age are used predominantly in the accompanying data because there was no six-month sampling at Olokele or for the fall crop at Olaa and Pioneer. Moreover, there appeared to be a luxury consumption of both nitrogen and potassium at six months in several of the experimental sites.

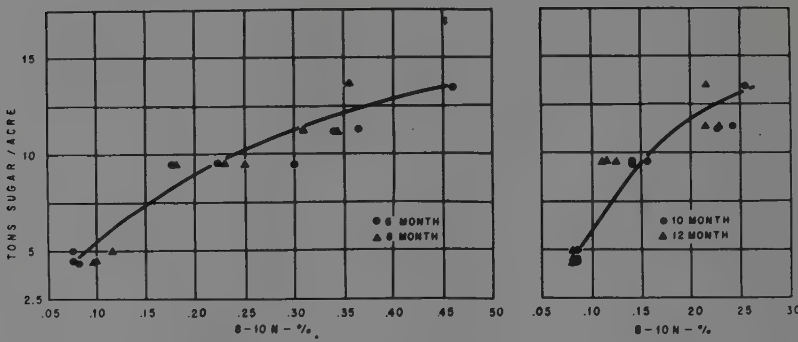


Figure 44. The relation of sugar yields to 8–10 N values determined at various ages
Pioneer Mill Co.

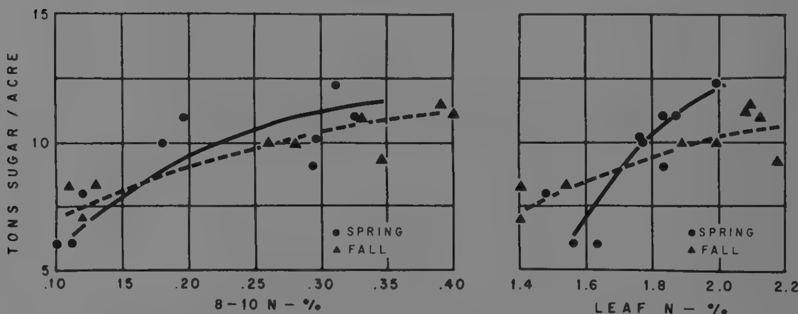


Figure 45. The relation of sugar yields to plant N—8 mo.—Lihue Plantation Co.

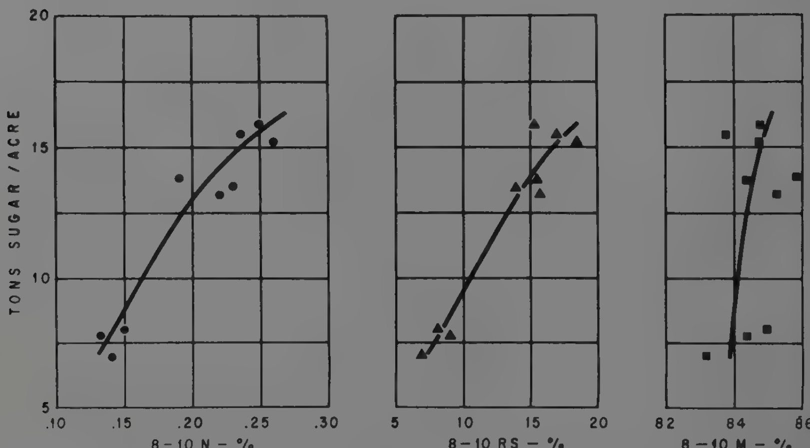


Figure 46. The relation of sugar yields to 8–10 N, 8–10 RS and 8–10 M—8. mo.
Oahu Sugar Co.

Nitrogen Composition and Yield

A. At Individual Plantations

The data in Figures 44, 45, 46 and 37A to 41A in Appendix A point out the following significant facts concerning the relationship of plant N and yields of sugar (TSA) when analyzed at each plantation:

1. A relationship between plant N and TSA holds true at different ages between six and 12 months (Figure 44). The curves become steeper at 10 and 12 months due to the normal decrease in composition with time following nitrogen fertilization.

2. All curves begin to flatten as the 8–10 N exceeds about the 0.3 per cent level and the LN is above about 2.0 per cent. These values confirm those suggested by Burr (Haw. Sugar Tech. Rpt., 1956, p. 44) for averages of samples taken at 6, 8, 10 and 12 months of age.

3. There is little difference between the stalk and leaf tissues at any given plantation with respect to the amount of scatter around the respective yield curves.

4. The curve for each plantation has its own shape, generally speaking. With the possible exception of Olaa, the curves for the spring and fall crops are different. This should be expected because of the different environmental conditions at a given age for the two plantings.

5. It is significant to note that the curves relating 8–10 reducing sugars and 8–10 moisture with yields (Figures 46, 40A and 41A) have the same shape as the N-TSA curves. 8–10 RS, especially, are highly correlated with TSA and the curves almost parallel those for 8–10 N. This emphasizes the close dependency of reducing sugars on the nitrogen content of the plant.

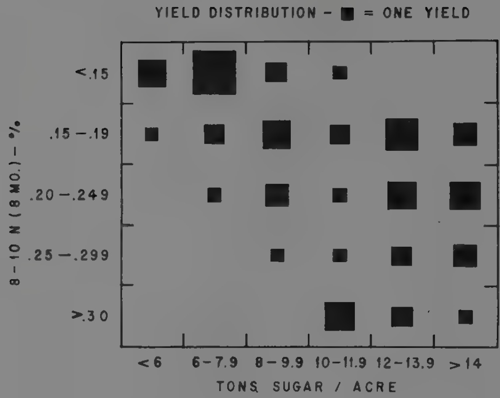


Figure 47. The distribution of sugar yields in relation to 8–10 N at 8 months of age.

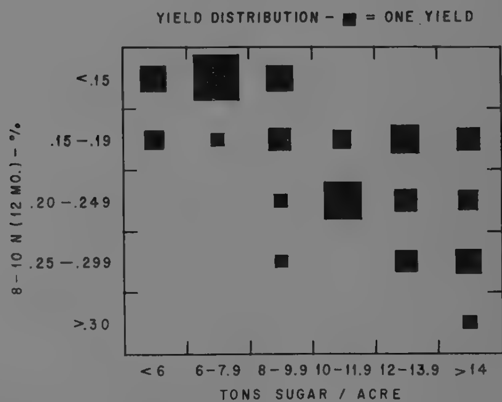


Figure 48. The distribution of sugar yields in relation to 8–10 N at 12 months of age.

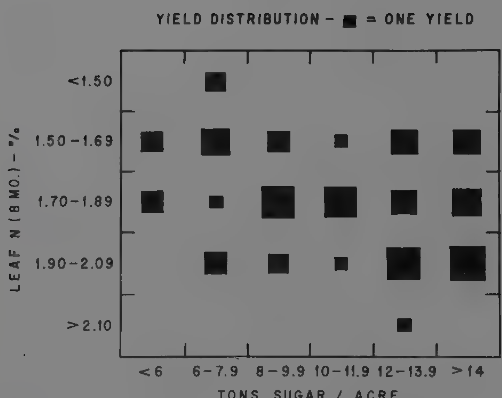


Figure 49. The distribution of sugar yields in relation to LN at 8 months of age.

B. Group Analyses

Due to the effect of factors other than plant N on the variation in cane yields from plantation to plantation, one should not expect a very high correlation between the nitrogen composition of plant tissues and sugar yields when all plantations are grouped together. The scatter of the various points was so large that it is not feasible to present the graphs in this publication. The following correlation coefficients were obtained for TSA (average of 21 and 24 months) against plant N (eight months):

TSA vs. 8–10 N	=0.584
TSA vs. leaf N	=0.523

The empirical distribution graphs in Figures 47, 48 and 49 show the wide variations in yields as related to nitrogen composition. The following generalized statements may be made from these results:

1. Only between one-fourth and one-third of the yield variations between plantations can be attributed to differences in nitrogen composition.

2. As far as 8–10 N is concerned, most of the low yields of sugar occur at low N levels. There are few high sugar yields at low N levels and vice versa, few low yields at high N levels.

3. It would appear that at eight months of age the 8–10 N should be above 0.30 per cent. At 12 months, this value is between 0.25 and 0.30 per cent.

4. The yield distribution pattern with respect to leaf N is not as pronounced as with 8–10 N. Both high and low yields were obtained at LN levels ranging from 1.50 to 2.00 per cent. However, the majority of the yields above eight TSA took place at LN levels above 1.70 per cent.

Potassium Composition and Yield

Only Grove Farm, Lihue, Olaa, and the site of the fall planting at Pioneer, showed definite responses to potash fertilization. These responses were in line with the available soil potassium analyses (Figure 23). The data in Figure 50 show the TSA:8–10 K curves for the aforementioned plantations. The following points from these curves are of interest:

1. Although the curves exhibit the same general shapes as those for N-TSA, the response per unit of 8–10 K is not as marked as for 8–10 N.

2. There is a tendency for the curves to flatten at 8–10 K values of between 0.6 and 0.8 per cent. At Pioneer, the 8–10 K for 400 pounds K_2O was only slightly in excess of 0.4 per cent, which is inadequate to give a picture of the curve at higher compositions.

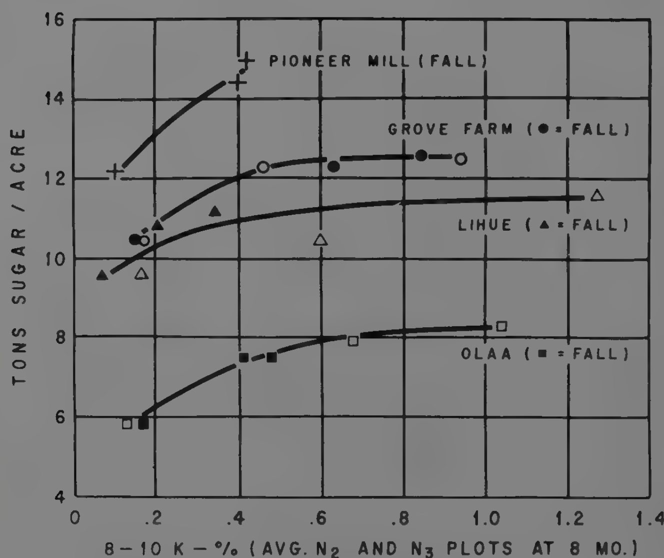


Figure 50. Percentage yield response as related to the 8-10 K composition of no-nitrogen plots.

SECTION G

YIELD RESPONSE IN RELATION TO COMPOSITION

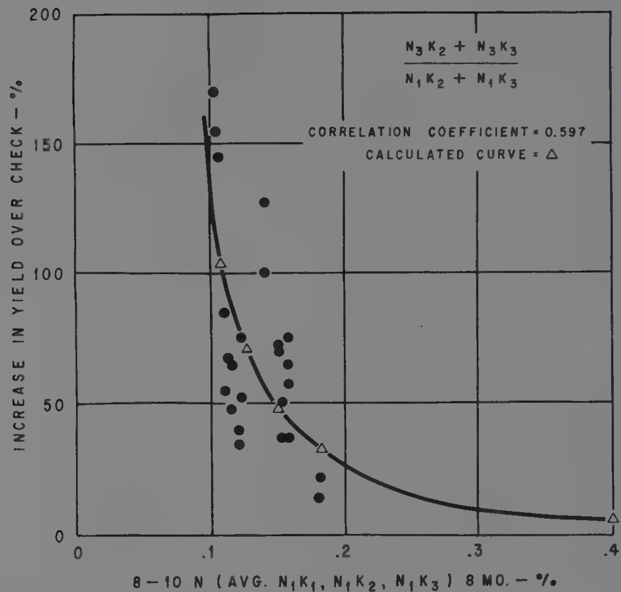


Figure 51. Percentage yield response as related to the 8–10 N composition of no-nitrogen plots.

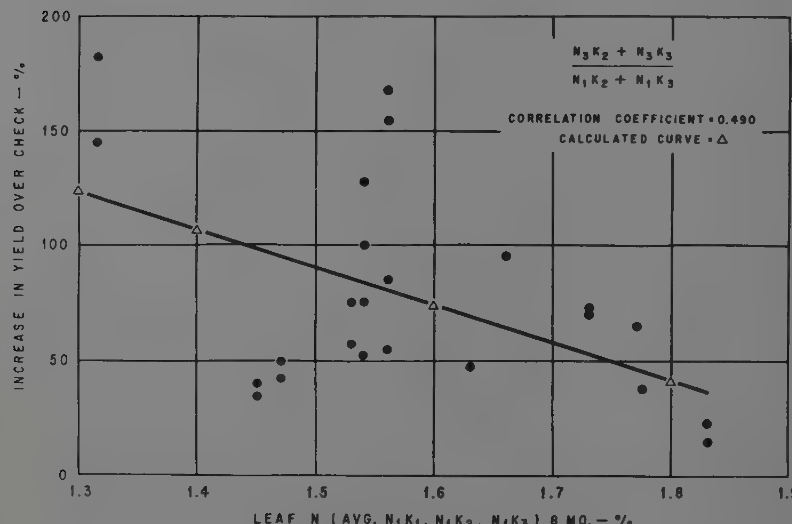


Figure 52. Percentage yield response as related to the leaf N composition of no-nitrogen plots.

The discussions in Section F showed the yield in terms of tons of sugar per acre at 21 and 24 months to the composition of plant tissues in the early stages of growth. It is the purpose of this section to present yield responses in terms of percentage increases over the check for both nitrogen and potash fertilization as related to plant composition of the check. Such an analysis should provide information which should enable one to establish plant composition levels for estimating the need for fertilizer applications.

Nitrogen Responses

The curves in Figures 51 and 52 show the percentage increase in yield over the check obtained with the application of 300 pounds N per acre. These yield increases were obtained by combining the yields of the K_2 (200 pounds) and K_3 (400 pounds) plots. The plots with no potash applications were omitted so as to remove any effects of potash deficiencies. The following generalizations seem obvious from these results:

1. The correlation coefficients relating the percentage increase in yields to the nitrogen composition of plant tissues from no nitrogen checks are not too satisfactory since only between 25 and 36 per cent of the variation can be explained by the nitrogen composition of the check.

2. The correlation coefficient of 0.597 for 8–10 N is superior to the 0.490 for the leaf N.

3. The percentage increase obtained by N fertilization rises rapidly when the 8–10 N of the checks falls below about 0.175 per cent at eight months of age. The calculated curve shows a distinct flattening when the N levels exceed about 0.3 per cent. This value corresponds rather closely to the data presented in Figures 44, 45, 47, 37A, 38A and 40A.

4. The scatter of the experimental data around the calculated curve for the leaf N values is too wide to permit any generalizations.

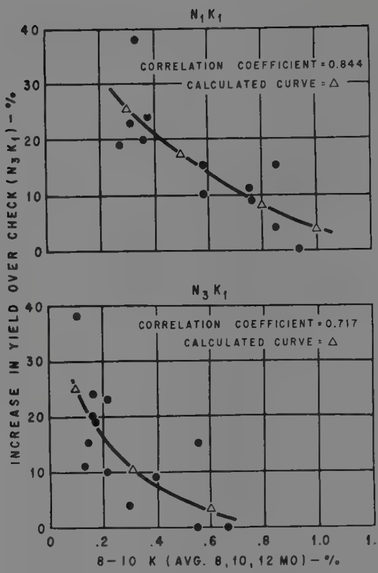


Figure 53. Percentage yield response as related to the 8–10 K composition of no-potash plots.

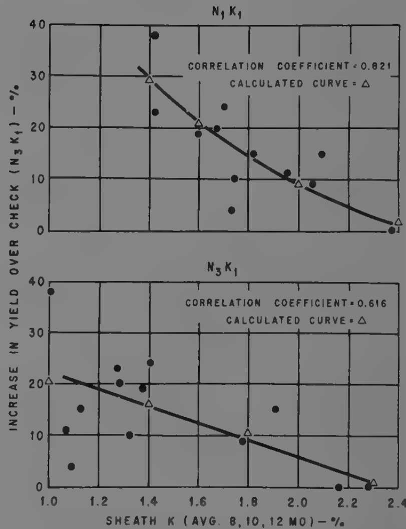


Figure 54. Percentage yield response as related to the sheath K composition of no-potash plots.

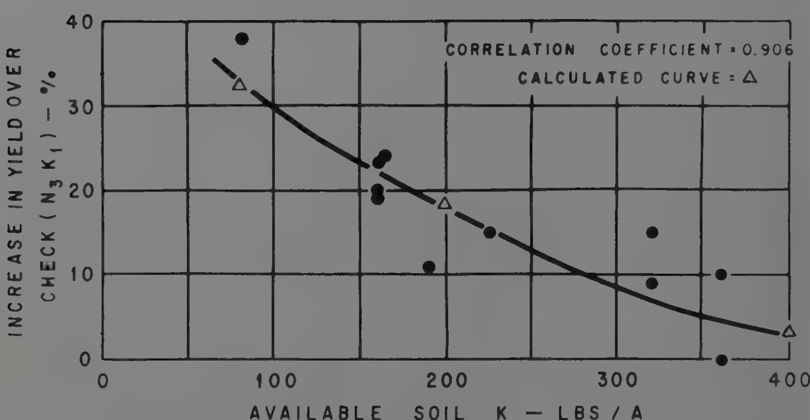


Figure 55. Percentage yield response as related to the available soil K of unfertilized plots.

Potash Responses

The potash response curves are shown in Figures 53, 54 and 55. The upper portions of Figures 53 and 54 represent the K values in the unfertilized check, N_1K_1; the lower portions are for the N_3K_1 plots. The two had to be separated because of the N effect upon K composition, as discussed in Section D. The data from these curves permit the following conclusions:

1. The K-% increase-in-yield curves show higher correlation coefficients than similar curves for N.

2. Although the 8–10 K values are slightly more highly correlated than sheath K, there is little to choose between the two tissues as far as reliability is concerned.

3. The N effect upon the K values of plant tissues is clearly shown in both Figures 53 and 54. This effect exhibits itself in two ways. First, the correlation coefficients for the N_1K_1 plots are higher than those for N_3K_1. Second, nitrogen lowers the composition values above which there is little response to potash fertilization. For example, in Figure 53 for 8–10 K, there is little response in yields in the absence of N when the K values are above about 1.0 per cent; in the presence of N, this figure is lowered to about 0.7 per cent. In Figure 54 for sheath K, little response is obtained in the absence of N when the K values are above 2.4 per cent; in the presence of N, this figure is lowered to about 2.3 per cent. Burr (Hawaiian Planters' Record, 55: 106, 1955) suggested an 8–10 K level of about 0.66 per cent, above which little response to potash fertilization may be expected. Clements and coworkers (Hawn. Agr. Exp. Sta. Ann. Rpt., 1946, pp. 108–111) suggested 2.25 as a satisfactory level for sheath K. Referring now to Figure 23 in Section C, it is seen that a sheath K level of about 2.2 per cent corresponds to an available soil K value of 325 pounds per acre. For 8–10 K, the corresponding value is about 0.8 per cent.

4. The highest correlation with the percentage increase in yields is found in Figure 55 in which available soil K is compared with fertilizer response. Here the correlation coefficient is 0.906 as compared with 0.6 to 0.7 when plant tissues from N-fertilized plots are used (which will be the standard case under plantation conditions). The curves in Figure 55 suggest a value of about 400 pounds per acre of available K above which one should expect little or no increase from potash fertilization. This is higher than the 325 pound sufficiency figure established by Ayres (unpublished—see Figure 42A in Appendix A). It is worthy to note in Figure 42A, however, that no potash fertilizer is recommended above 400 pounds per acre of available soil K. These data again emphasize the value of available soil K analysis in fertilizer recommendations.

SECTION H

COMPOSITION AS AN INDEX OF FERTILIZATION

The comprehensive experiments, which have produced the large amount of data that have been the basis of these discussions, had as one of the major objectives the clarification of existing differences of opinion within the Hawaiian sugar industry with respect to the use of plant and soil analyses for fertilizer recommendations. It is believed that this objective has been achieved. It will be the purpose of this section to analyze as objectively as possible the significance of the preceding data as a basis for evaluating the fertilizer needs of a given crop. Before entering into such an analysis, however, it is necessary to keep at least two important points in mind. First, no method of plant or soil analysis is absolutely perfect and exceptions to any established composition value will always occur. Second, a chemical analysis of either plant or soil, or both, is no substitute for good agriculture in the production of any crop, including sugar cane. Consequently, soil and plant analyses are only guideposts on the road of good fertilizer practices and not the road itself.

COMPARISON OF PLANT TISSUES

Essentially, the major discussion centers around the relative advantages and disadvantages of stalk versus leaf and leaf-sheath tissues. Although the preceding results include both the basal internode and the 8–10 internodes, the present analysis will be confined to the 8–10 internodes as representing the stalk tissues. This is primarily based upon the practicalities involved in the field usage of plant analyses.

Plant Nitrogen

Points in favor of 8–10 N over leaf N: Although alcohol-soluble nitrogen was also determined in these studies, the extremely high correlation between alcohol-soluble and total nitrogen and the greater ease of using total nitrogen make the latter more feasible to use. Even though there is a satisfactory correlation between 8–10 N and LN at six months of age, the 8–10 N has the following points in its favor as a logging tissue:

1. The N-decay curve with time is more uniform and less fluctuating.
2. The sensitivity to nitrogen fertilization is much higher at all levels of nitrogen. Leaf N registered significant responses only at deficiency levels of N.
3. The correlation between yield and N composition is slightly higher with a more distinct yield distribution pattern.
4. The correlation between yield response as related to the N composition of unfertilized plants is significantly higher. The scatter of the response data for leaf N is quite large.
5. Nitrogen can be determined upon the same samples as other necessary constituents.

Points in favor of leaf N over 8–10 N: Even though there is a satisfactory correlation between 8–10 N and leaf N, the major advantages for using leaf N as an index tissue are operational and not chemical. They are:

1. By using the leaf punch technique, sampling the leaves is much easier than sampling the stalk. Moreover, the stalk is not destroyed. This advantage, which is quite important if one is interested only in nitrogen, disappears when one has to sample other tissues for other constituents.
2. Leaf samples can be obtained at an age earlier than six months if it is necessary to have earlier samples in a logging procedure.

Plant Potassium

Although the 8–10 K is slightly more sensitive than sheath K for reflecting potash fertilizer applications, the high correlation coefficient of 0.917 between the two values suggests that both are reliable indexes of the K composition of the plant. The advantage of the 8–10 K over sheath K-index is that it is determined on the same tissue as nitrogen and other constituents, whereas the latter is based upon a sugar-free tissue, thereby requiring a sugar analysis.

Plant Phosphorus

The lack of correlation of sheath P with both basal P and 8–10 P, with available soil P and with yield responses (other experimental data) makes the 8–10 P a much superior tissue for logging purposes. Moreover, 8–10 P is determined upon the same sample as other constituents.

Plant Moisture

The similar behavior of sheath M and 8–10 M with age (Figure 15) would indicate that either of these values might be used for logging procedures. However, the correlation between 8–10 M and sheath M shown in Figure 29 is only fair. Moreover, the smaller range of sheath M when compared with 8–10 M throws some doubt upon the sensitivity of the former. The 8–10 M has the advantage of being determined upon the same tissue as N and other constituents.

Plant Total Sugars

In this study, stalk plant sugars were determined to check on their behavior under various conditions and not to serve as logging indexes. The data have shown that the 8–10 TS are considerably higher than sheath TS, as should be expected. They also indicate that there is a general increase in 8–10 TS with age with only a slight variation in sheath TS.

PROCEDURE FOR USING SOIL AND STALK ANALYSES FOR EVALUATING FERTILIZER NEEDS OF CANE

It is not the purpose of this presentation to outline in detail recommended fertilizer practices. These will vary from plantation to plantation, depending upon local factors and management desires. However, inasmuch as the big bulk of experimental evidence, both old and recent, indicates the superiority of applying fertilizers early in the life of the crop as compared with late applications, these procedures contemplate that the great majority of the fertilizer will be added by eight to 10 months of age.

The analyses will be restricted to plant moisture, plant nitrogen, soil and plant phosphorus and potassium. Calcium suggestions will be presented as a separate phase of the discussion. Total sugars will not be determined since their value in helping to determine fertilizer programs is extremely questionable.

Step 1. Soil Analyses

1. Obtain soil samples and determine available K and P (pH and available Ca may also be determined when necessary).

2. Plan K and P fertilization according to charts shown in Figures 42A and 43A in Appendix A.

Step 2. Nitrogen Fertilization

1. Plan N fertilization for first six to eight months on basis of accumulated

evidence from replicated field experiments as well as previous field practices for variety and location in question.

Step 3. Plant Analyses

1. Sample 8–10 internodes at 6, 8 and 10 months of age.
2. Determine 8–10 M, 8–10 N, 8–10 K and 8–10 P

6-month sampling—Determine 8–10 M. If higher than 86, other determinations are unnecessary. If lower, check 8–10 N and K.
8-month sampling—Determine all four constituents.
10-month sampling—Check on 8–10 M, N and K.

3. Check the plant composition to determine the success of the fertilization program in Steps 1 and 2 and to find out what additional amounts, if any, of N and K are necessary. The levels of M, N, K and P at these ages for varieties 37-1933 and 44-3098 should be somewhat as follows:

	M (H_2O) %	*N* %	*K* %	P %
6 mos.	86–88	>0.35	1.0	0.038–0.046
8 mos.	84–86	0.28–0.35	0.7–0.8	0.032–0.04
10 mos.	83–85	0.24–0.28	0.7–0.8	0.032–0.04

Step 4. Applying Additional Fertilizer

1. If deficiencies of N or K are observed, additional applications should be in the order of 75 to 100 pounds of N or K_2O per acre. Smaller amounts will rarely affect plant composition. This additional amount of N added at this stage of development will rarely affect juice quality negatively.

2. In the case of P deficiencies, it is only under special conditions that surface applications of P_2O_5 will be effective.

Calcium Determinations

Calcium becomes a limiting factor of growth only under acid soil conditions. In acid soil areas, the soil samples can be analyzed as follows:

1. Determine pH.
2. Determine available Ca on those soils where the pH value dictates, and evaluate Ca needs according to the chart in Figure 44A in Appendix A.

SECTION I

COST ANALYSIS OF DIFFERENT METHODS

In the previous sections, data were presented which showed that the 8–10 internode can be used as a single tissue for determining plant moisture, nitrogen, phosphorus, potassium and sugars. The analyses showed the 8–10 internode to be a superior tissue for interpreting N and P composition values in terms of fertilizer needs.

Since the 8–10 internodes have a scientific advantage in certain respects, it is important to know how the method of evaluating fertilizer needs by combining soil and 8–10 analyses compares with the leaf and leaf-sheath logging procedures from the standpoint of costs. An industrial engineering analysis of Oahu plantations with experience in both methods of logging has produced the information summarized in Table 2. The difference of $0.73 per sample in favor of the 8–10 internode technique consists of the extra cost of sampling an extra tissue (leaf punch N) and the determination of total sugars with the leaf-leaf sheath method.

Due to considerable variation between plantations in the use of logging techniques, it is rather difficult to arrive at exact cost comparisons that apply generally throughout the industry. However, the summarized data in Table 3 give a fairly close approximation of average conditions. The big difference between the two methods lies in the larger number of samples used in the leaf-leaf sheath technique. This difference of about $550 per 1,000 acres in favor of the 8–10 internode-soil analysis procedure may not have too much economic significance, even though it does represent a distinct potential saving.

TABLE 2. ECONOMIC ANALYSIS OF CROP LOGGING METHODS

Cost Per Sample

Method:	Leaf-Leaf Sheath					8–10 Internode				
	Labor		Material	Service	Total	Labor		Material	Service	Total
Operations	Man-Hrs.	Dollars	Dollars	Dollars	Dollars	Man-Hrs.	Dollars	Dollars	Dollars	Dollars
Field Sampling	0.62	$1.11		$0.95	$2.06	0.53	$0.96		$0.95	$1.91
Determine Moisture & Weight; Prepare for Analysis	0.22	$0.40			$0.40	0.14	$0.26			$0.26
Laboratory Analysis										
Nitrogen	0.25	$0.50	$0.05		$0.55	0.25	$0.50	$0.07		$0.57
Phosphorus	0.24	$0.48	$0.03		$0.51	0.24	$0.48	$0.03		$0.51
Potassium	0.14	$0.28			$0.28	0.14	$0.28			$0.28
Total Sugars	0.22	$0.44	$0.02		$0.46					
Sub Total	0.85	$1.70	$0.10		$1.80	0.63	$1.26	$0.10		$1.36
Total	1.69	$3.21	$0.10	$0.95	$4.26	1.30	$2.48	$0.10	$0.95	$3.53

TABLE 3. SUMMARIZED COSTS PER 1,000 ACRES OF LOGGING METHODS

Leaf and leaf sheath logging	$949.60[1]
8–10 logging	187.80[2]
Soil analyses	208.30
Soil analyses + 8–10 logging	396.10

[1]13 samplings per sampled area of 50 acres with 3 P and K analyses during boom stage.

[2]3 samplings per sampled area of 50 acres with 1 P and 2 K analyses during boom stage.

APPENDIX A

SUPPLEMENTARY GRAPHS

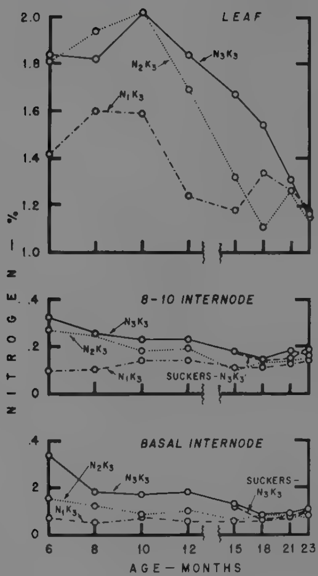


Figure 1A. The effect of age on N levels — spring plant. Grove Farm Co.

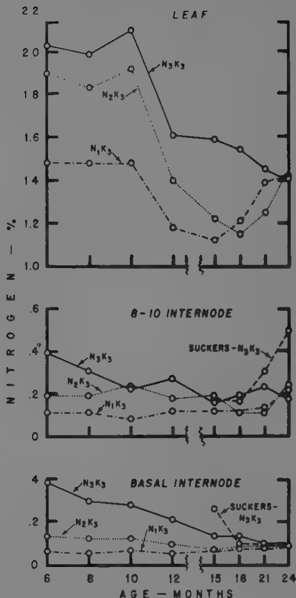


Figure 2A. The effect of age on N levels — spring plant. Lihue Plantation Co.

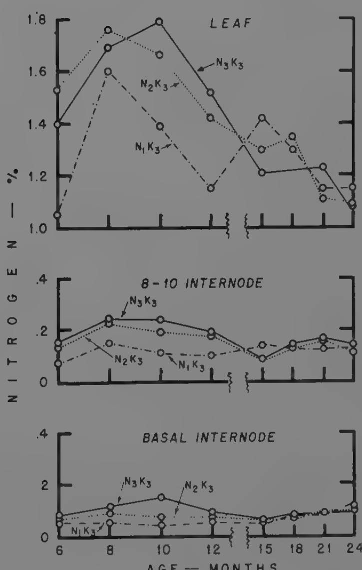


Figure 3A. The effect of age on N levels—spring plant—Oahu Sugar Co.

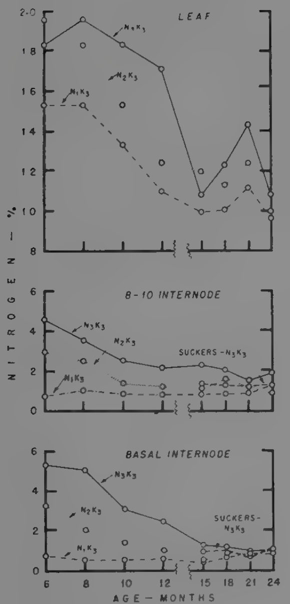


Figure 4A. The effect of age on N levels—spring plant. Pioneer Mill Co.

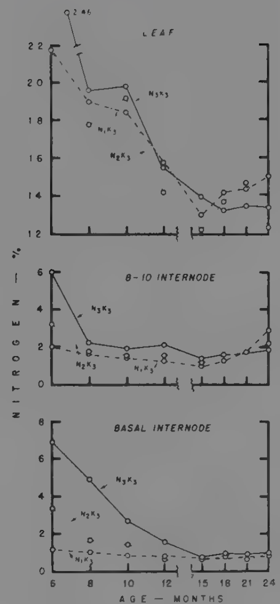
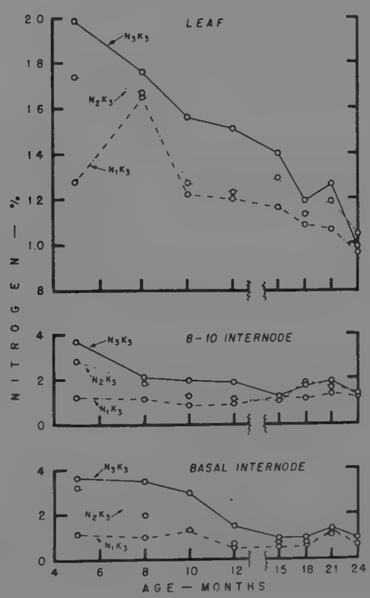


Figure 5A. The effect of age on N levels—spring plant. Olaa (Puna) Sugar Co.

Figure 6A. The effect of age on N levels—Block II—Olokele Sugar Co.



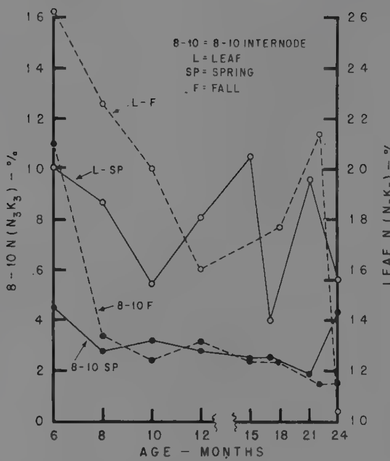


Figure 7A. The relation of N composition changes with age to time of plant. Kekaha Sugar Co.

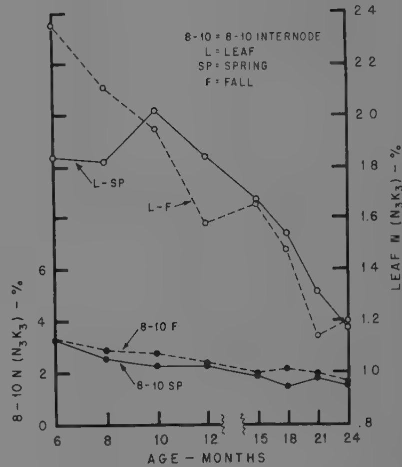


Figure 8A. The relation of N composition changes with age to time of plant. Grove Farm Co.

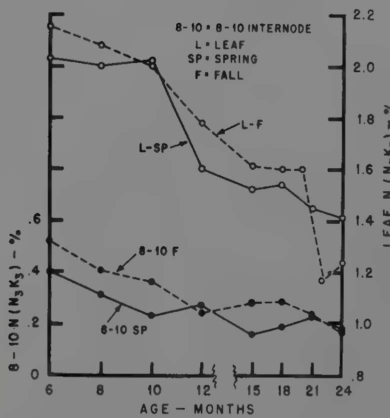


Figure 9A. The relation of N composition changes with age to time of plant. Lihue Plantation Co.

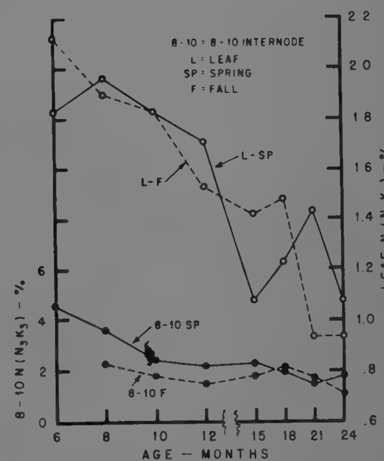


Figure 10A. The relation of N composition changes with age to time of plant. Pioneer Mill Co.

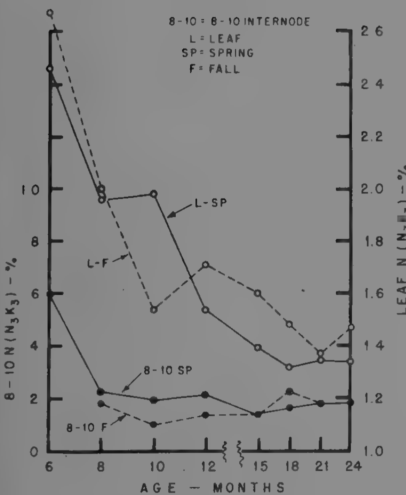


Figure 11A. The relation of N composition changes with age to time of plant. Olaa (Puna) Sugar Co.

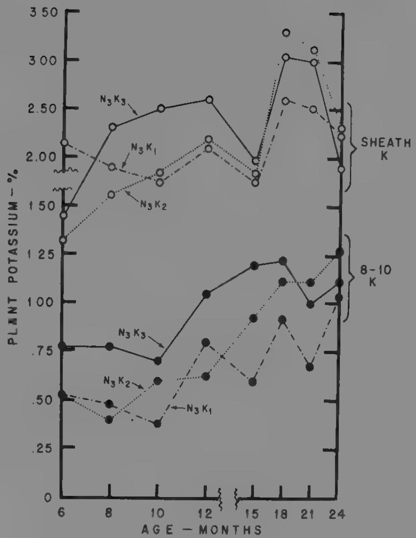


Figure 12A. The effect of age on K levels—spring plant—Kekaha Sugar Co.

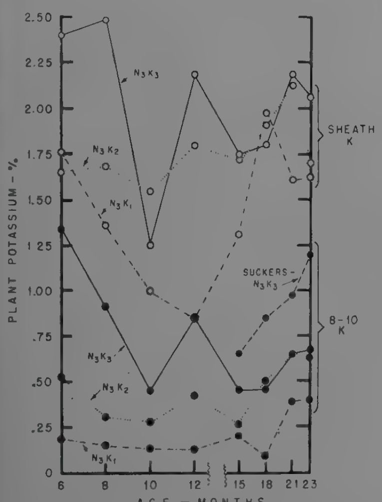


Figure 13A. The effect of age on K levels —spring plant—Grove Farm Co.

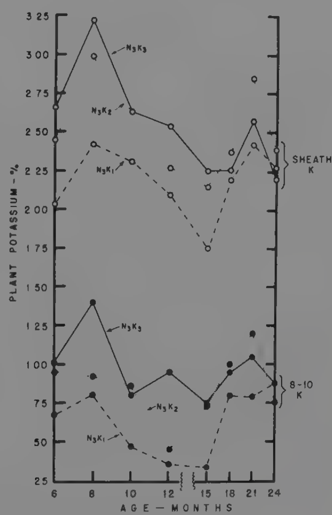


Figure 14A. The effect of age on K levels—spring plant. Oahu Sugar Co.

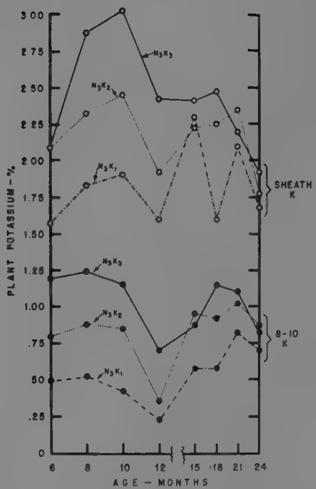


Figure 15A. The effect of age on K levels—spring plant. Pioneer Mill Co.

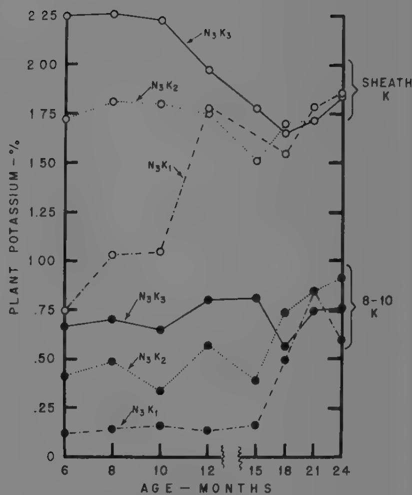


Figure 16A. The effect of age on K levels —spring plant—Olokele Sugar Co.

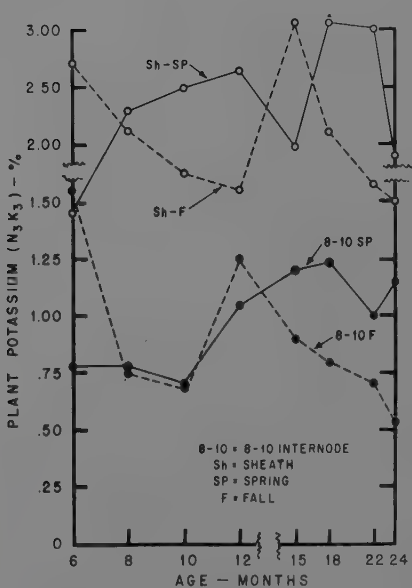


Figure 17A. The relation of K levels to time of plant—Kekaha Sugar Co.

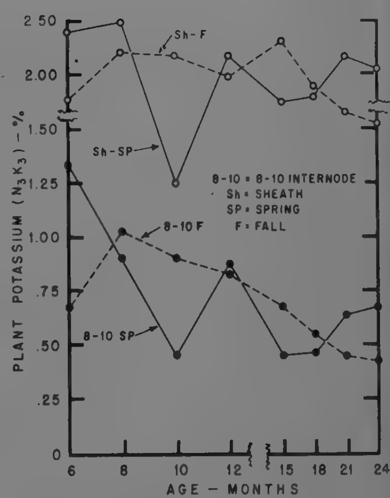


Figure 18A. The relation of K levels to time of plant—Grove Farm Co.

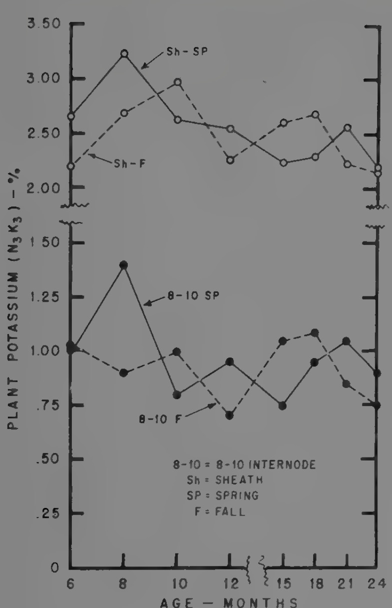


Figure 19A. The relation of K levels to time of plant—Lihue Plantation Co.

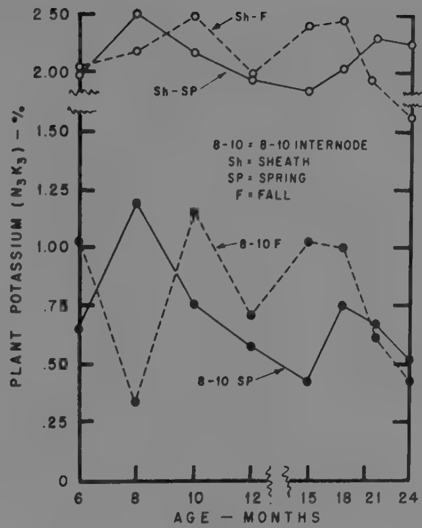


Figure 20A. The relation of K levels to time of plant—Oahu Sugar Co.

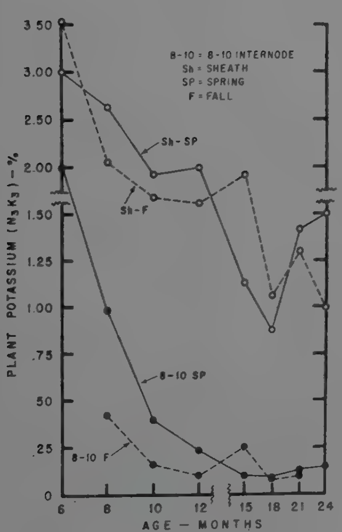


Figure 21A. The relation of K levels to time of plant. Olaa (Puna) Sugar Co.

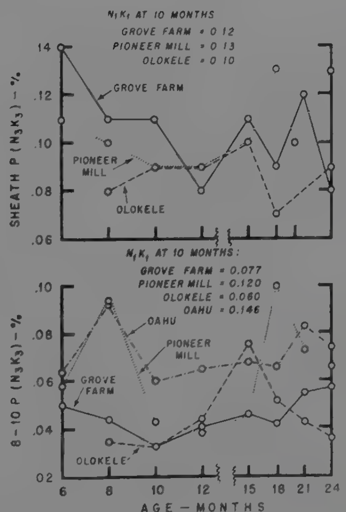


Figure 22A. The relation of age to changes in the P composition of cane tissues.

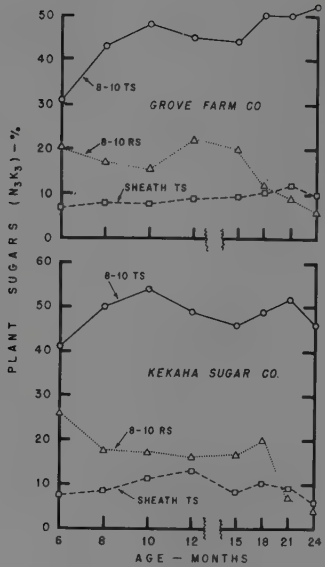


Figure 23A. The relation of age to changes in the sugar levels in cane tissues.

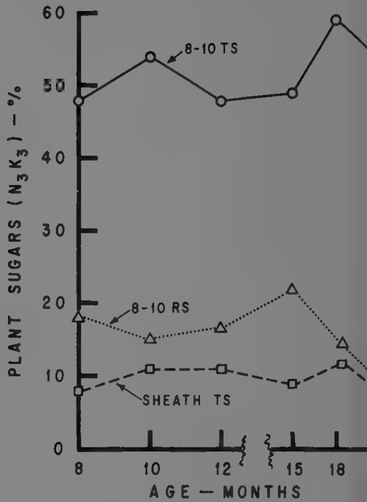


Figure 24A. The relation of age to chan[ges] in the TS and RS levels in cane tissu[es]. Olokele Sugar Co.

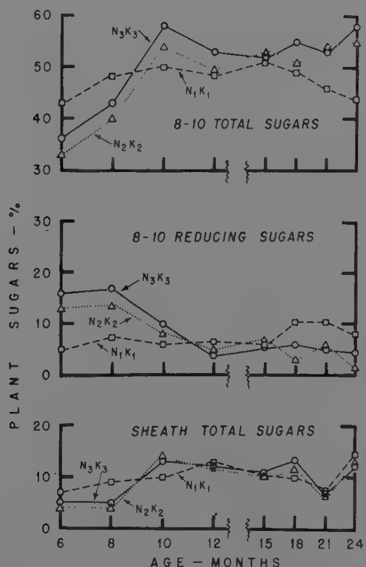


Figure 25A. The effects of fertilization on the TS and RS levels in cane tissues. Olaa (Puna) Sugar Co.

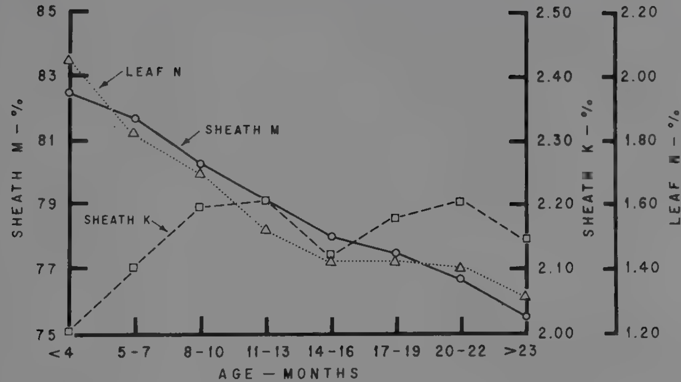


Figure 26A. Sheath moisture-leaf nitrogen-sheath K relationships with age for 32–8560 at Waialua Agricultural Co. (after Silva and Humbert, Spec. Release 125, 1955—data from Figures 1, 9 and 23).

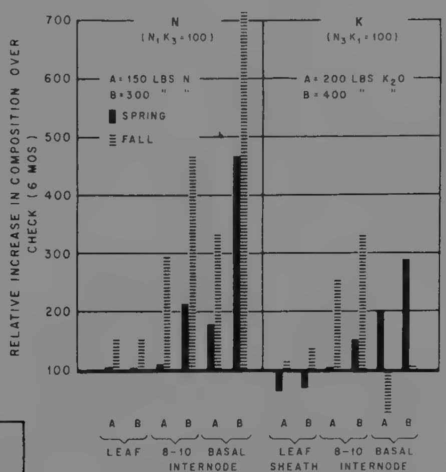


Figure 27A. The relative response of cane tissues to N and K_2O fertilization. Kekaha Sugar Co.

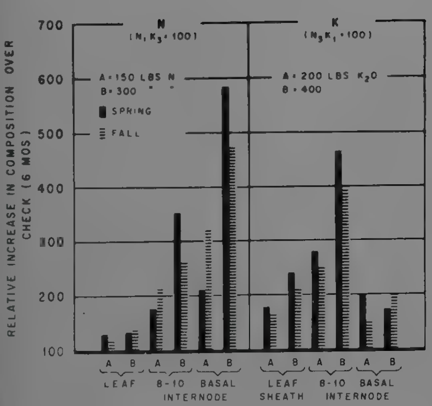


Figure 28A. The relative response of cane tissues to N and K_2O fertilization. Lihue Plantation Co.

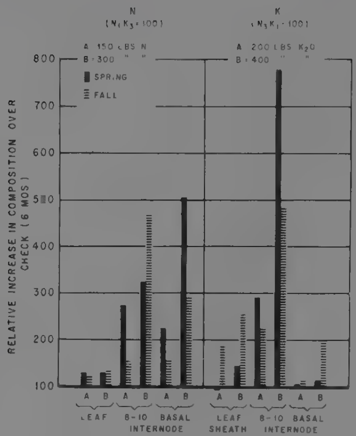


Figure 29A. The relative response of cane tissues to N and K_2O fertilization. Grove Farm Co.

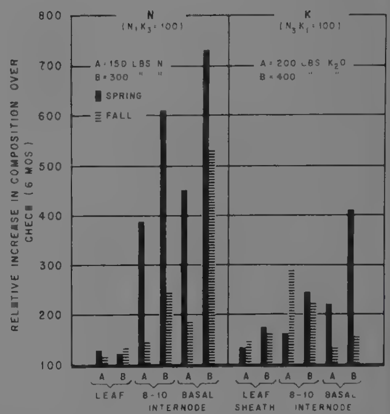


Figure 30A. The relative response of cane tissues to N and K_2O fertilization. Pioneer Mill Co.

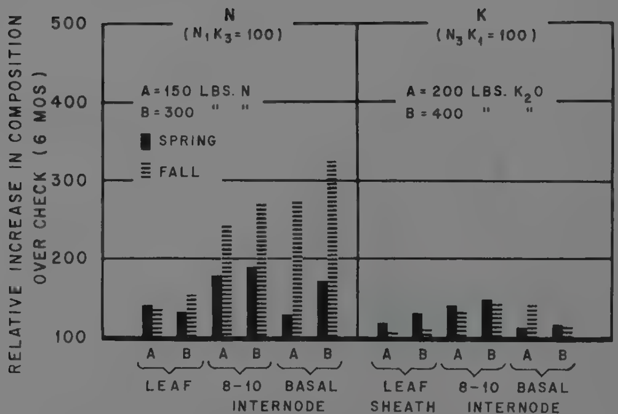


Figure 31A. The relative response of cane tissues to N and K_2O fertilization—Oahu Sugar Co.

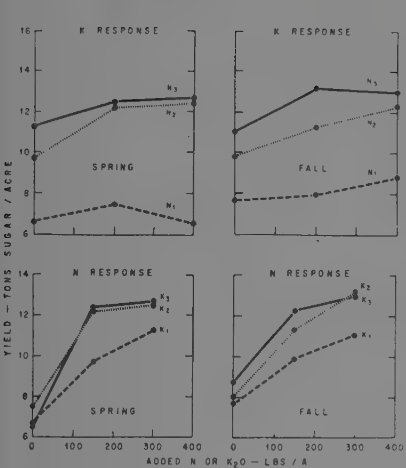


Figure 32A. The effect of N and K_2O fertilization upon sugar yields.
Grove Farm Co.

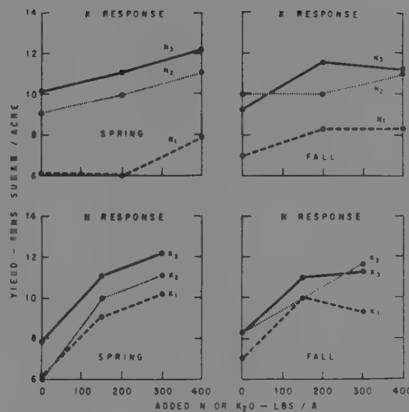
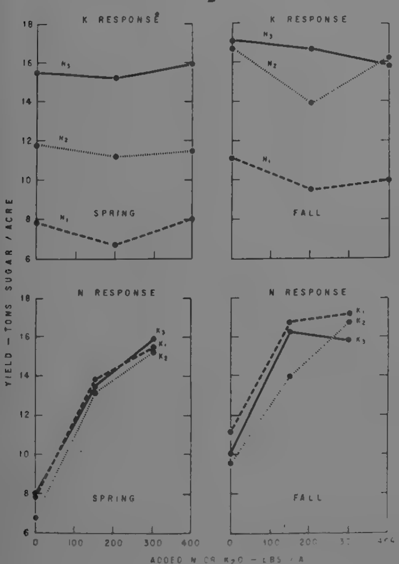


Figure 33A. The effect of N and K_2O fertilization upon sugar yields.
Lihue Plantation Co.

Figure 34A. The effect of N and K_2O fertilization upon sugar yields.
Oahu Sugar Co.



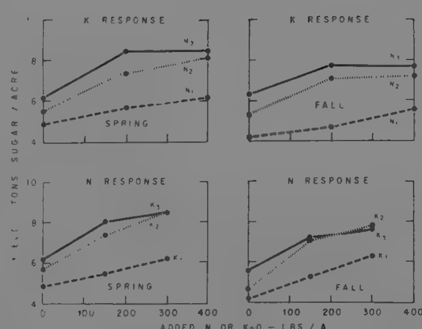


Figure 35A. The effect of N and K_2O fertilization upon sugar yields.
Olaa (Puna) Sugar Co.

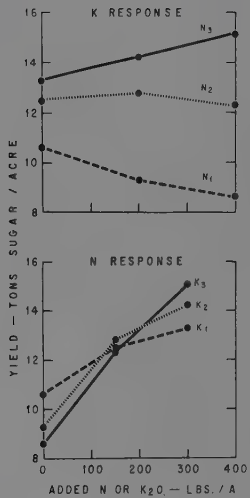


Figure 36A. The effect of N and K_2O fertilization upon sugar yields—Olokele Sugar Co.

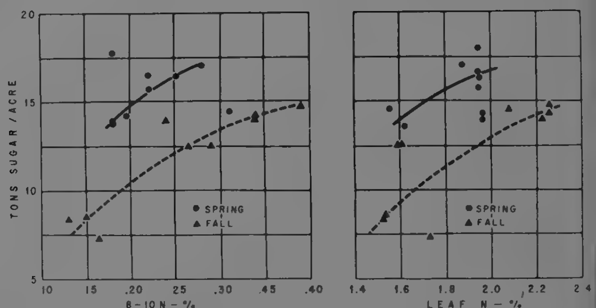


Figure 37A. The relation of sugar yields to Plant N—8 mo. Kekaha Sugar Co.

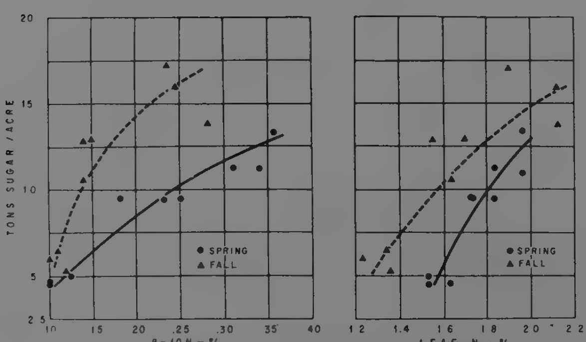


Figure 38A. The relation of sugar yields to Plant N—8 mo. Pioneer Mill Co.

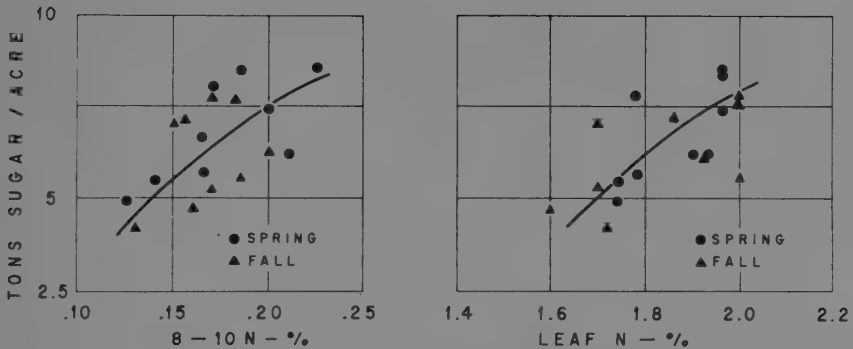


Figure 39A. The relation of sugar yields to Plant N—8 mo.
Olaa (Puna) Sugar Co.

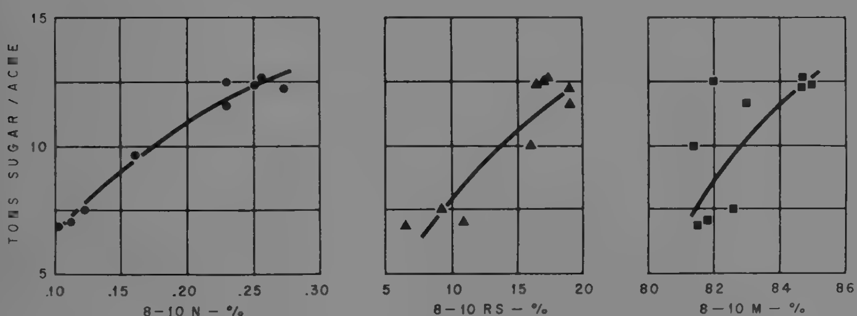


Figure 40A. The relation of sugar yields to 8–10 N, 8–10 RS and 8–10 M—
8 mo.—Grove Farm Co.

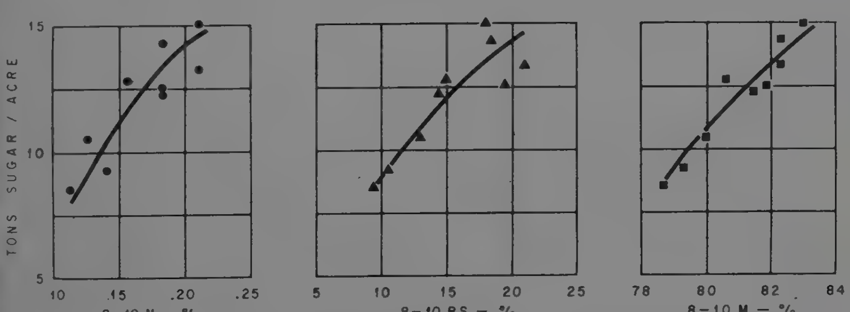


Figure 41A. The relation of sugar yields to 8–10 N, 8–10 RS and 8–10 M—
8 mo.—Olokele Sugar Co.

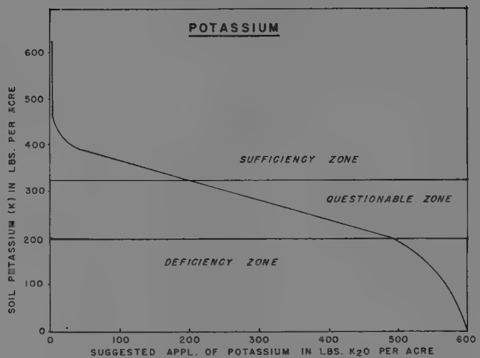


Figure 42A. Potash fertilization recommendations in relation to the available K in soil. (by A. S. Ayres)

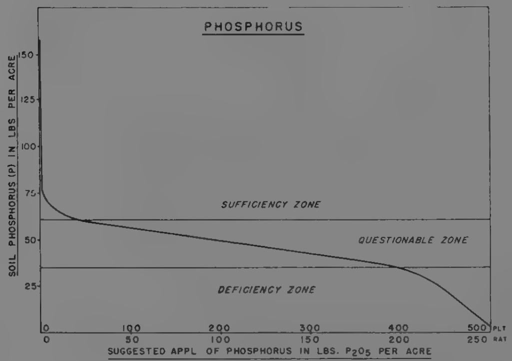


Figure 43A. Phosphate fertilization recommendations in relation to the available P in soil. (by A. S. Ayres)

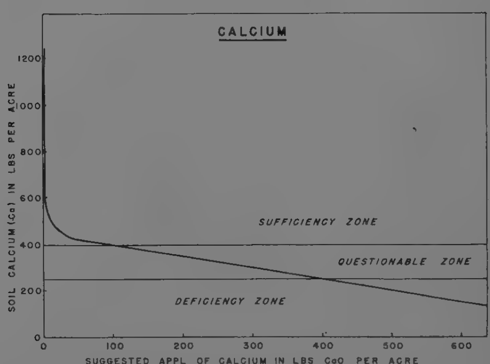


Figure 44A. Calcium addition recommendations in relation to the available Ca in soil. (by A. S. Ayres)

APPENDIX B

INTRODUCTION TO GROUP TEST No. 11

INTRODUCTION TO THE GROUP TEST No. 11

Time of Planting x Age of Harvest x Amounts of Nitrogen x Amounts of Potash

R. P. Humbert, J. A. Silva, G. O. Burr, H. A. Walker, Jr., and W. W. G. Moir*

Personnel and Location:

Group Test No. 11 was an Age of Harvest x Nitrogen x Potash test with two times of planting on the six American Factors plantations and Olokele Sugar Company. The plantation personnel who have contributed to this test are as follows:

Erich Spillner, W. J. Crittenden and staff	Grove Farm
George Y. Ewart and staff	Kekaha
Ronald Toyofuku and staff	Lihue
Lambert Kerns and staff	Oahu Sugar
David Young and staff	Olaa
Philip Conrad and staff	Pioneer Mill
James Deacon, Donald Ballinger and staff	Olokele

The staffs of the Island Representatives and the Departments of Agronomy, Chemistry, Experimental Statistics, and Physiology and Biochemistry of the Experiment Station have also participated.

The contributions of the late Ralph J. Borden deserve special mention. It was his desire to evaluate methods of crop control in a well-replicated test over a wide range of soil and climatic conditions.

Objectives:

The objectives of Group Test No. 11 are as follows:

1. To define the critical levels of N and K in plant tissues which are affected by time of planting, age, and rates of nitrogen and potash fertilization.

2. To compare and evaluate the total and alcohol-soluble nutrients in the stalk tissues with the total nutrients in the leaf blades and sheaths.

3. To find the effect on yield of three levels of N and three levels of K at three ages of harvest with two times of start.

4. To find the relationships of the various plant nutrients with each other and with yield.

5. To study variations in the nutrient levels of primaries and suckers.

Treatments:

The treatments imposed in this experiment with the symbols used in the following reports are listed as follows:

Time of Planting:	Spring T_1	Fall T_2	
Age of Harvest:	18 Mos. A_1	21 Mos. A_2	24 Mos. A_3
Nitrogen:	0 lbs. N_1	150 lbs. N_2	300 lbs. N_3
Potash:	0 lbs. K_a	200 lbs. K_b	400 lbs. K_c

*Principal Agronomist, Assistant Agronomist, Principal Physiologist, Expt. Sta., HSPA; Agriculturist, and Director of Agricultural Activities, Plantation Division, American Factors Ltd.

Varieties:

In order to gain information on the two leading cane varieties, Olokele, Kekaha and Pioneer Mill planted 37-1933, while Grove Farm, Lihue, Oahu Sugar and Olaa planted 44-3098.

Fertilization:

The fertilizer was all applied earlier than present-day plantation practice in order to study different levels of reserves of nutrients in the cane plants and the effect of treatment on the utilization of these reserves. All the fertilizer was applied prior to the collection of the first stalk samples. Early applications of fertilizer favor the younger ages of harvest and the data will be interpreted accordingly. The fertilizer schedules are as follows:

Plot Treatments	With Seed			2-3 Mos.	At 4-5 Mos.		Total		
	N	P_2O_5	K_2O	N	N	K_2O	N	P_2O_5	K_2O
N_1 K_a	0	200	0	0	0	0	0	200	0
N_1 K_b	0	200	100	0	0	100	0	200	200
N_1 K_c	0	200	200	0	0	200	0	200	400
N_2 K_a	50	200	0	50	50	0	150	200	0
N_2 K_b	50	200	100	50	50	100	150	200	200
N_2 K_c	50	200	200	50	50	200	150	200	400
N_3 K_a	100	200	0	100	100	0	300	200	0
N_3 K_b	100	200	100	100	100	100	300	200	200
N_3 K_c	100	200	200	100	100	200	300	200	400

Age at which Actual Fertilizer Applications were Made

SPRING

Plantation	With Seed	2-3 Mos.	4-5 Mos.
Grove Farm	3/20/52	3.0 Mos.	5.0 Mos.
Kekaha	5/2/52	2.2	4.8
Lihue	3/15/52	3.1	5.3
Oahu Sugar	4/22/52	5.2	6.4
Olaa	4/18/52	2.1	3.8
Olokele*	4/14/52	2.0	4.0
Pioneer	3/21/52	3.6	5.1

* 0# N had 44# N applied

FALL

Plantation	With Seed	2-3 Mos.	4-5 Mos.
Grove Farm	8/12/52	3.1 Mos.	6.4 Mos.
Kekaha	10/13/52	2.0	4.0
Lihue	9/10/52	4.2	7.2
Oahu Sug.*	8/28/52	3.2	5.8
Olaa F123	9/25/52	2.5	4.3
F 50A	10/7/52	2.1	3.9
Pioneer	8/12/52	2.4	4.8

* Cane 1 mo. old at time of first application

Soil samples from proposed sites were collected and analyzed to insure against deficiencies of phosphorus and calcium. Superphosphate was applied at the rate of 200 lbs. P_2O_5/A with the seed at planting time.

Individual Plot Layout:

Each plot consisted of eight rows 70 feet long. The four middle rows of all plots were used for yield data. There were guard lines on each side of the plot. One of these was used for tissue sampling and the other for stalk census studies. The outside row on either side was kept as a guard row in the plots that were sampled. The following is a diagram of the plot in which tissue samples were collected:

```
   10'              50'               10'
G -----  ______________________  -----   G = Guard rows
S -----  ______________________  -----   S = Sample rows
H -----  ______________________  -----   H = Rows to be harvested
H -----  ______________________  -----         for yield
H -----  ______________________  -----   C = Census
H -----  ______________________  -----   XXXXX = Census area
C -----  _____XXXXX____________  -----         (10' of row)
G -----  ______________________  -----   :   : = Growth measure-
                                                  ment (optional)
```

Tissue Sampling Procedure:

The tissue sampling was done only on the plots of the 24-month age of harvest. Samples were collected when the cane was 5, 6, 8, 10, 12, 15, 18, 21, and 24 months old. Leaf sheath and blade samples were collected at each of these sampling dates, starting at five months. Stalk samples were collected starting with the six months sampling or eight months in the fall plant. When secondaries and suckers were sufficiently developed, they were also collected and analyzed separately by foliar and stalk methods. The logs of the secondaries and suckers started at the 10-15 month of age period.

The procedure followed in collecting the tissue samples was standardized on all seven plantations. Briefly, this was the procedure followed:

Three primary stalks representing the population at the time of sampling were cut from each of the 24-month age of harvest plots. The stalks were cut at ground level and separated into the basal 3 internodes, the 8-10 internodes, leaf sheaths 3, 4, 5, and 6, and leaf blades 3, 4, 5, and 6. The stalks were composited by treatment, i.e., two plots per treatment making six stalks per treatment. The sampling was done in the morning before 9:30 a.m.

Chemical Analysis:

The leaf blade tissue from composited leaves 3, 4, 5, and 6, was used for total nitrogen determinations, while the sheath tissue from composited sheaths 3, 4, 5, and 6, was used for total phosphorus, potassium, sugar and moisture determinations. For the stalk, slices were taken from each of the internodes 8, 9, and 10, as well as from the basal internodes of each treatment. The slices from the 8-10 and the basal section were analyzed separately for total nitrogen, potassium, and phosphorus, as well as for alcohol-soluble nitrogen and potassium. Reducing, sucrose, and total sugar determinations were also made on the alcohol extract from the slices. The chemical analysis of the foliar tissues was done by the plantation laboratories. The analysis of the stalk tissues was done by the Department of Physiology and Biochemistry, with the Chemistry Department cooperating.

Stalk Census:

A permanent 10-foot stalk census area was established in each plot of the 24-month age of harvest. Stalk counts were made prior to each tissue sampling, starting when the cane was eight months old. No stalks were removed in the census areas.

Ripening:

The ripening of all treatments and ages of harvest were the same. Water was withheld for 30 days prior to harvest.

Harvesting:

The blocks of each age of harvest were arranged in strips that could be harvested without damage to the adjoining blocks. The actual age of harvest for the proposed age-of-harvest treatments ranged from 17.0-19.2 months for the 18-month harvest, 20.5-22.8 months for the 21-month harvest, and 23.6-26.1 months for the 24-month harvest. Grove Farm had no 21-month harvest for the spring plant, but harvested both the 21- and 24-month blocks at 24.0 months of age. Olokele had only the spring planting and it was harvested at 25 months of age. All plantations burned the cane prior to harvest, except Olaa, where the cane was harvested unburned. Only the inside four lines of each plot were harvested for yield data on all plantations. The boundary separation of the inside four lines was made either before or while cutting the cane. The slash-cut method of separation was used on all plantations.

All of the plantations hand-cut the cane in the plots and loaded it by machine. Transportation from the field to the mill was either by trucks, railroad cars, or a combination of both. The weight of the cane in the plots was obtained either by bundling it and weighing the bundles or by getting the weight of the truck or railroad car load. In all but one case, 100 per cent of the cane harvested was weighed. The 24-month harvest for the spring plant at Olaa had weight taken on only 50 per cent of the cane harvested. Mill crusher juice samples taken from running juice from 100 per cent of the cane harvested from each plot were used for juice analysis on all plantations except Olokele, Kekaha and Olaa. Olokele obtained mill crusher juice samples from 75 per cent of the cane from each plot. Kekaha and Olaa used the Cuban A Mill to obtain the juice samples. 300 pounds of cane from each plot were run through the Cuban A Mill for the samples on these plantations.

Statistical Analysis:

The statistical analysis of the yield and tissue data are being done by the Department of Experimental Statistics and Agronomy. Some of the analysis of the tissue data is being computed with IBM equipment while the rest of it is being done with desk calculators. Attempts are being made to do as much of the computation on IBM equipment as possible.

* * * * * * * *

EDITOR'S NOTE

Further parts of Special Release No. 116 will be issued upon completion of the analysis and interpretation of the data. Each part should be considered as a progress report.

APPENDIX C

YIELD DATA FROM THE SIX AMERICAN FACTORS PLANTATIONS AND OLOKELE SUGAR COMPANY

YIELD DATA FROM THE SIX AMERICAN FACTORS PLANTATIONS AND OLOKELE SUGAR COMPANY TESTS FOR THE SPRING AND FALL PLANTINGS OF THE PLANT CROP

W. T. Federer, R. P. Humbert, and R. K. Tanaka

* * * * * * * * * * *

INTRODUCTION

This part of the report on the six American Factors plantations and the Olokele Sugar Company tests deals with the analyses of the yield data. These data consist of the following five characters:

Tons of sugar cane per acre - TCA
Juice percentage or yield per cent cane - Y%C
Tons of sugar per acre - TSA
Tons of sugar cane per acre per month - TCAM
Tons of sugar per acre per month - TSAM

The analysis of each of the six American Factors tests is presented for the spring planting, for the fall planting, and for the spring and fall plantings combined. This set of analyses is followed by combined analyses on the six American Factors tests for the spring planting, and for the spring and fall plantings combined. This is followed by a section dealing with the analyses of the Olokele test, which is presented separately because the experimental procedure and design were different from those used in the six American Factors tests.

One of the objectives of this study was to determine the effect of three nitrogen applications, three potash applications, three ages of harvest, and two times of planting, on yield characteristics in sugar cane. The different treatments were:

Nitrogen applications -	zero	(N_1)
	150 lbs. /A	(N_2)
	300 lbs. /A	(N_3)
Potash applications -	zero	(K_a)
	200 lbs. /A	(K_b)
	400 lbs. /A	(K_c)
Age of harvest -	18 months	(A_1)
	21 months	(A_2)
	24 months	(A_3)
Time of planting -	Spring	(T_1)
	Fall	(T_2)

The above four factors were used in all combinations to obtain a 3x3x3x2 factorial set of treatments.

The nitrogen applications were applied at three different times, with one-third of the total being applied at or near time of planting, one-third at two to three months after planting, and one-third at four to six months after planting. The potash levels were put on in two equal applications, with the first one being at or near the time of planting, and the last half going on four to six months later. The three ages of harvest were approximately at the specified ages. Time of planting varied considerably, with the spring planting begun between 3/15/52 and 5/2/52, and the fall planting started between 7/29/52 and 10/13/52. The length of time between spring and fall plantings was not six months for all tests. This interval varied from three and one-half months for Oahu Sugar Company to almost six months for Lihue, with the other tests ranging between these limits.

A uniform application of 200 pounds of P205 was made to the experimental area in order to insure that phosphorus should not be a limiting factor. However, in the plant tissue studies, it was noted that at some plantations phosphorus in the plant was below the tentatively established

The authors appreciate the advice of D. D. Mason in the analysis of a part of these data.

critical level for a number of months during the first year. Despite the uniform application of 200 pounds of P205 per acre, phosphorus may have been deficient during certain stages of growth. Such a deficiency would not allow full expression of the other factors and would tend to give decreased yields of sugar cane and of sugar per acre.

EXPERIMENTAL DESIGN AND ANALYSES

The experimental design used is described in the memorandum from R. J. Borden to R. P. Humbert, 2/7/52. The design at the six American Factors plantations was essentially a non-randomly arranged split-split-plot design with the two times of planting arranged in the largest plots which were subdivided to obtain the two replicates or blocks. The first split in the replicate was age of harvest; the age of harvest plot was split into nine split-split-plots on which the nine treatment combinations of nitrogen and potash were applied. The nine treatment combinations were laid out in a so-called balanced arrangement, which was systematic in nature. The age of harvest treatments were laid out in a similar pattern.

Due to the non-randomized nature of the experimental design, the tests of significance in an analysis of variance are only approximate, with the degree of approximativeness being unknown. The breakdown of the degrees of freedom for a split-split plot of the above form is:

Source of Variation	D.F.	Mean Square
Time of planting - T	1	
Replicates within planting	2	E_a
Age of harvest - A	2	
A x T	2	
Error (b)	4	E_b
Nitrogen levels - N	2	
Potash levels - K	2	
N x K	4	
N x T	2	
K x T	2	
N x K x T	4	
N x A	4	
K x A	4	
N x K x A	8	
N x A x T	4	
K x A x T	4	
N x K x A x T	8	
Error (c)	48	E_c
Total	107	

Since the factors used are considered to be fixed effects, i.e., they represent the population of effects, the error mean square for the time-of-planting mean square is E_a, for the age-of-harvest and for the AxT-interaction means squares is E_b, and for the other mean squares is E_c.

The Olokele test was a three nitrogen levels of application x three potash levels of application factorial set of treatments in four complete blocks. Only one age of harvest (24 months) and one time of planting (4/10/52) were used in this test. The lowest nitrogen level was 44 pounds of nitrogen applied per acre in a single dose four days after planting. The phosphorus application of 192 pounds of P205/A was applied in the form of ammonium phosphate, rather than as superphosphate as in the American Factors tests. The systematic arrangement of the nine treatments allows for only an approximate analysis of the data.

Despite the systematic layout, it is doubted that the estimated treatment differences are subject to any biases at the individual plantations. Certainly, there should be no bias in the estimated treatment differences over all plantations. It is realized that the estimated error variances are biased, but it is suspected that these biases are relatively small. Even though tests of significance are performed in the usual manner for a randomized design, the interpretation and application of the results should take into account the systematic nature of the designs.

The five per cent level of significance is used in this study as in other studies on this set of experiments. The five per cent level is on a <u>per line</u> in the analysis of variance basis. The

error could be made as five per cent per experiment, or as five per cent per the set of six experiments. In the analyses, it must be remembered that some of the effects will be significant due to chance sampling fluctuations. Therefore, if biological theory and other evidence is contradicted by a test of significance, we reject the results of the test or else withhold our conclusions until more data are available. If an effect falls just short of the prescribed level, we draw the same conclusions that we would have drawn had it fallen at just the prescribed level.

ANALYSES FOR EACH AMERICAN FACTORS TEST

With regard to expected significance of the various mean squares in each test, the time of planting, the age of harvest, the nitrogen, and the potash mean squares, should all be relatively large for yields of sugar cane and of sugar per acre. For Y%C, the relative size of the mean square is not so well known; here the age-of-harvest mean square should be relatively large. For all characters then, the main interest is more on the interactions with age-of-harvest, time-of-planting, and nitrogen levels, than on these main effects themselves. The time-of-planting mean squares from each test are poorly estimated since there is only one replicate on the two plantings. The test for time of planting, which is not a uniform time and interval, is best made in the combined analyses for the six tests. The differences in time of planting results at each plantation are not only seasonal but are also due to a location effect since the two time-of-planting plots were in quite different locations for some tests.

GROVE FARM

Spring Planting:

The three times of harvesting and the three ages of harvest for the spring planting of Grove Farm experiment were:

Harvest	Date Harvested	Age in Months
A_1	9/29-30/53	18
A_2	3/22-25/54	24
A_3	3/22-25/54	24

The experiment was planted on 3/22-25/52. The A_2 harvest was not at the prescribed 21 months of age, but was harvested along with the A_3 plots at 24 months. Therefore, the analysis of variance for this setup differs from the prescribed one in the following respects:

Source of Variation	Degrees of Freedom for Prescribed Test	Degrees of Freedom for Grove Farm
Blocks	1	1
Age of Harvest - A	2	1
Error (a)	2	3
Nitrogen levels - N	2	2
Potash levels - K	2	2
N x K	4	4
A x N	4	2
A x K	4	2
A x N x K	8	4
Error (b)	24	32
Total	53	53

In order to keep the combined analyses relatively simple, the following procedure was adopted to estimate the treatment yields of TCA for the A_2 harvest.

(i) In Block I, calculate the difference between the nine plots harvested at the A_1, 18 months, harvest and between the nine plots which were supposed to have been harvested at 21 months. Divide this difference by 5.77 months, the differences in age harvested, to obtain a per month increase in TCA. The per month increase of TCA is multiplied by three. This adjustment factor is subtracted from the nine plots which were supposed to have been harvested at 21 months in Block I.

(ii) The same type of adjustment described in (i) is used for the data from Block II.

The above adjustments for the 18 plots, which were supposed to have been harvested at 21 months but which were harvested at 24 months, were used to obtain adjusted TCA yields. The Y%C results were left unadjusted, since the A_1 and A_3 results were nearly identical. Then, with the adjusted TCA figures and the unadjusted Y%C figures for the A_2 harvest, the analyses for the five characters were completed. Since two constants were computed from the data and since these two constants, the adjustment factors for Blocks I and II, were used to adjust the data, some adjustment in the degrees of freedom for the prescribed analysis of variance should be made. It would require some study to determine which sets of degrees of freedom to adjust. One degree of freedom would have to be subtracted from the age-of-harvest degrees of freedom, leaving one degree of freedom. The other degree of freedom would probably come out of the error (b) degrees of freedom. However, since the results would be little affected, except for age of harvest, this adjustment was not made.

The mean yields for the five yield characters from the Grove Farm experiment are presented in Table 1. The analyses of variance are given in Table 2. The 18-month harvest was considerably higher in TCAM and TSAM than the 24-month harvest. All characters except Y%C were greatly affected by the different nitrogen levels, with the 300-pound application giving higher yields for all four characters. The largest effect was between the zero application and the 150-pound application means.

The different potash levels had no apparent effect on Y%C, but did affect the other four characters. The 200- and 400-pound applications resulted in almost identical yields. Both were considerably above the zero application means for TCA, TSA, TCAM, and TSAM. Response was expected since the level of exchangeable potassium in the soil ranged from 66 to 76 ppm, which is below the established critical level.

The remaining effects were not significantly larger than their respective error mean squares. The significance of the various effects would not be altered if a correction in the error (b) degrees of freedom had been made.

Table 1

Mean Yields for the Various Categories from the Experiment at Grove Farm (Variety 44-3098, spring planting)

Category		Means For				
		TCA	Y%C	TSA	TCAM	TSAM
Age of harvest - 18 mos.	A_1	80.9	12.1	9.9	4.44	.542
21 " (est'd)		84.5	12.1	10.1	4.03	.483
24 "	A_3	80.0	12.2	9.7	3.33	.406
Zero lbs. Nitrogen/A -	N_1	55.4	12.1	6.7	2.67	.322
150 "	N_2	91.8	12.4	11.4	4.42	.549
300 "	N_3	98.2	11.9	11.7	4.70	.559
Zero lbs. Potash/A -	K_a	73.6	12.3	9.0	3.54	.433
200 "	K_b	85.5	12.2	10.4	4.11	.500
400 "	K_c	86.3	12.0	10.3	4.15	.497
General mean		81.8	12.1	9.9	3.93	.477

Table 2

Analyses of Variance for Yield Characters from the Grove Farm Experiment, Spring Planting

Source of Variation	Degrees of Freedom	Mean Squares For				
		TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	765.39	1.30	5.74	1.8556	.0143
Age of Harvest - A	2	104.42	.10	.77	5.5976*	.0839*
Error (a)	2	57.46	.24	.39	.1629	.0014
Amounts of Nitrogen - N	2	9612.23**	1.06	140.37**	21.7627**	.3225**
Amounts of Potash - K	2	908.13**	.35	11.06**	2.1072**	.0261**
N x K	4	90.28	.34	1.63	.1912	.0035
A x N	4	89.68	.91	.96	.1328	.0034
A x K	4	13.97	.09	.35	.0453	.0011
A x N x K	8	27.95	.03	.49	.0552	.0011
Error (b)	24	47.75	.44	.83	.1083	.0019
Total	53					
Coefficient of Variation (%)		8.5	5.4	9.0	8.7	9.0

* Observed F exceeds tabulated F at 5 per cent point
** Observed F exceeds tabulated F at 1 per cent point

Fall Planting:

The fall planting part of the Grove Farm experiment was planted on 8/12/52. The three times of harvesting and the three ages are:

Harvest	Date Harvested	Age in Months
A_1	3/17/54	19
A_2	6/7-9/54	22
A_3	8/10-13/54	24

The mean yields and the analyses of variance are presented in Tables 3 and 4, respectively. In this part of the experiment, there appeared to be a deterioration of juices at the 24-month harvest. This naturally raises the question about the over-ripeness of the crop.

All five characters were significantly affected by the different nitrogen applications. For TCA, TSA, TCAM, and TSAM, the 150-pound nitrogen treatment was considerably above the zero nitrogen application, the 300-pound nitrogen mean was above the 150-pound, but not by so large a margin as the difference between the N_2 and N_1 means. For Y%C, the N_1 and N_2 means were almost identical, but the N_3 mean was significantly lower than either of the other two.

For the different potash treatments, the 400-pound treatment is significantly above the check treatment, K_a, for all characters. Except for Y%C, the 400-pound potash means are larger than the 200-pound potash means. The differences between the K_c and the K_b means for Y%C and for TSA are not significant as compared to the LSD's. The fact that these differences are significant for TSAM and not for TSA is a rounding error and age factor difference. The conclusion reached is that the increase in both TSA and TSAM for the 400-pound potash application over the 200-pound potash application probably is a real difference. There is little doubt but that the K_c treatment gave increased TCA yields, as well as TCAM yields, over the K_b treatment. Response was expected since the level of exchangeable potassium at the start of the experiment was 55 ppm and 41 ppm in the check plots at harvest.

Table 3

Mean Yields for Various Categories from the Grove Farm Experiment (Variety 44-3098, fall planting)

Category		Means For				
		TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 19 Mos.,	A_1	81.6	12.5	10.2	4.26	.531
22 "	A_2	91.1	12.3	11.1	4.17	.507
24 "	A_3	97.5	10.4	10.0	4.06	.418
Zero pounds Nitrogen/A,	N_1	67.5	12.2	8.1	3.12	.378
150 "	N_2	94.0	12.0	11.2	4.35	.523
300 "	N_3	108.8	11.0	11.9	5.02	.554
Zero pounds Potash/A,	K_a	85.0	11.2	9.4	3.93	.437
200 "	K_b	87.2	12.2	10.5	4.02	.486
400 "	K_c	98.0	11.8	11.4	4.53	.533
General mean		90.1	11.7	10.4	4.16	.485

Table 4

Analyses of Variance for Yield Characters from the Grove Farm Experiment, fall planting

Source of Variation	Degrees of Freedom	Mean Squares For				
		TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	121.80	.10	1.18	.3456	.0034
Age of Harvest - A	2	1154.07	25.34**	6.34	.1695	.0634
Error (a)	2	474.62	.64	3.52	.9336	.0066
Amounts of Nitrogen - N	2	7870.74**	7.49**	73.92**	16.7477**	.1590**
Amounts of Potash - K	2	866.61*	4.21*	19.04**	1.8928*	.0421**
N x K	4	79.40	.86	1.34	.2248	.0031
A x N	4	213.63	.10	2.14	.4054	.0052
A x K	4	40.35	.57	1.05	.1114	.0032
A x N x K	8	220.72	.25	2.12	.5221	.0049
Error (b)	24	135.77	.66	1.95	.2948	.0045
Coefficient of Variation (%)		14.1	6.9	14.0	14.2	14.2

* Observed F exceeds tabulated F at 5 per cent point
** Observed F exceeds tabulated F at 1 per cent point

Spring and Fall Planting Combined:

The mean yields and the analyses of variance for the spring and fall plantings of the Grove Farm experiment are given in Tables 5 and 6, respectively. The mean yields for the 24-month harvest for Y%C, TCAM, and TSAM are significantly lower than the A_1 harvest means. The nitrogen and potash treatments both affected TCA and TCAM. The higher levels gave significant increases over the lower levels. For TSA and TSAM, the zero plots for both the nitrogen and potash treatments were significantly lower than the means of the other plots. The means for the intermediate nitrogen and potash treatments were lower than the highest levels of application although not significantly so. For Y%C, the N_1 and N_2 means were identical, and both were significantly higher than the N_3 mean. The different potash levels apparently had no effect on Y%C.

The nitrogen treatments in the spring planting did not respond in the same manner as in the fall planting for three of the yield characters (Table 6). For Y%C, the N_3 mean was significantly

lower than the N_1 and N_2 means in the spring planting, but there were no significant differences among the three treatment means in the fall planting. For TSA and TSAM, the difference between the means for N_3 and N_1, and N_2 and N_1, were much larger for the spring planting than for the fall planting. This is the reason for the significant NxT interaction for TSA.

The significant KxT interaction for Y%C is caused by the reversal of the order of means for K_a, K_b, and K_c, as well as by the differences in magnitude in these means. There was almost no difference for the three potash treatments for the spring planting (Table 1); the order of yield was K_a, K_b, and then K_c. In the fall planting, the K_a treatment was significantly lower than K_b and K_c, and the order of yields was K_b, K_c, and K_a. For TCAM, the significant KxT interaction is caused by the fact that the difference K_c-K_a is smaller for the spring plant data than for the fall plant data, and the difference K_c-K_b is sizeable for the fall plant data but is negative and small for the spring plant data. The KxT interaction for TCA just falls short of the five per cent point. The apparent discrepancy for the two characters, TCA and TCAM, is due to the fact that the harvests were not at the prescribed ages. Therefore, if one is to conclude that there is a significant KxT interaction for TCAM, they must also conclude that the same interaction exists for TCA.

The reversal of the above situation is found for the NxA interaction for TCA and TCAM. The TCA mean square is significant while the TCAM interaction mean square is not. There probably exists a real NxA interaction for both TCA and TCAM. Increased tonnages are obtained from the A_3 harvest over the A_1 harvest for the N_3 treatment as compared to the zero nitrogen level. This undoubtedly results from the fact that the nitrogen application of 300 pounds per acre was sufficient to keep the sugar cane growing, thereby utilizing the additional time.

Table 5

Mean Yields for the Various Categories from the Experiment at Grove Farm (Spring and fall plantings)

Category		Means For			
	TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - A_1	81.2	12.3	10.0	4.35	.536
" A_2	87.8	12.2	10.6	4.10	.495
A_3	88.7	11.3	9.9	3.70	.412
Amount of Nitrogen - N_1	61.4	12.2	7.4	2.89	.350
N_2	92.9	12.2	11.3	4.39	.536
N_3	103.5	11.5	11.8	4.86	.557
Amount of Potash - K_a	79.3	11.8	9.2	3.74	.435
K_b	86.3	12.2	10.4	4.06	.493
K_c	92.1	11.9	10.9	4.34	.515
Age & Nitrogen - N_1A_1	60.3	12.3	7.4	3.23	.398
N_1A_2	59.5	12.7	7.5	2.77	.348
N_1A_3	64.5	11.6	7.3	2.69	.304
N_2A_1	90.4	12.8	11.5	4.84	.617
N_2A_2	94.5	12.4	11.7	4.41	.546
N_2A_3	93.8	11.5	10.7	3.91	.446
N_3A_1	92.9	11.9	11.1	4.97	.594
N_3A_2	109.5	11.6	12.6	5.11	.590
N_3A_3	108.0	10.9	11.6	4.50	.486
General Mean	85.9	11.9	10.2	4.05	.481

Table 6

Analyses of Variance for Yield Characters from the Grove Farm Experiment, Spring and Fall Plantings Combined

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Time of Planting - T	1	1851.74	4.25	7.37	1.4351	.0021
Blocks in Time of Planting - error (a)	2	443.60	.70	3.46	1.1006	.0089
Age of Harvest - A	2	605.50	11.35**	5.70	3.8520*	.1445**
A x T	2	653.02	14.09**	1.40	1.9150	.0028
Error (b)	4	266.03	.44	1.96	.5482	.0040
Amounts of Nitrogen - N	2	17221.10**	6.37**	208.21**	37.8946**	.4653**
Amounts of Potash - K	2	1485.17**	1.66	27.50**	3.3130**	.0623**
N x K	4	24.95	.98	1.27	.0708	.0023
N x T	2	261.87	2.18*	6.08*	.6158	.0162*
K x T	2	289.57	2.90**	2.60	.6870*	.0058
N x K x T	4	144.73	.21	1.70	.3453	.0076
N x A	4	270.79*	.61	2.59	.4943	.0079
K x A	4	32.52	.47	.97	.0889	.0029
N x K x A	8	135.00	.07	1.56	.3244	.0036
N x T x A	4	31.20	.39	.51	.0439	.0007
K x T x A	4	21.79	.19	.43	.0678	.0013
N x K x T x A	8	113.68	.21	1.04	.2530	.0024
Error (c)	48	91.76	.55	1.42	.1962	.0032
Coefficient of Variation (%)		11.9	6.2	11.9	11.6	11.9

* Observed F exceeds tabulated F at 5 per cent point
** Observed F exceeds tabulated F at 1 per cent point

KEKAHA

Spring Planting:

The Kekaha test was planted on 5/2/52 and the three times and ages of harvest were:

Harvest	Date Harvested	Age in Months
A_1	9/28-29/53	17
A_2	3/25/54	23
A_3	5/10/54	24

These differ somewhat from the prescribed dates in that the harvests would differ by three-month intervals starting at 18 months. In the Kekaha test, the interval between A_1 and A_2 is six months, while that between A_2 and A_3 is one and one-half months.

In addition to the above complications, the three plots receiving treatments 2c, 3a, and 3b in the A_2 age-of-harvest plots in one of the replicates were in an old ravine, and since the results were rather abnormal, the yields of TCA were estimated by the ordinary missing plot formulae for a randomized complete block design using the two A_2 plots as replicates and the nine treatments therein. It is realized that this is not the most efficient procedure, but it is sufficiently accurate for the purposes at hand. The actual Y%C figures for these three plots were used in the analyses. This means that the degrees of freedom for the error (b) mean squares will be 21 for characters TCA, TSA, TCAM, and TSAM, and will be 24 for Y%C.

The mean yields for the five characters from the Kekaha test, excluding the estimated values, are given in Table 7. The analyses of variance for these data are presented in Table 8. From the latter table, it is seen that the different ages of harvest significantly affected the Y%C and in turn TSA. Also, the later harvest dates did have more TCA than did the first harvest date, which also contributes to the significant differences for TSA. The Y%C at 17 months of age was

significantly lower than at either of the other ages. The second age of harvest was lower, although not significantly so, than the last age of harvest, A_3, with the difference in age being 1 1/2 months.

The different levels of nitrogen had a decided effect on TCA with relatively no effect on Y%C. The effect of nitrogen levels on TCA caused the significance of the nitrogen levels for the characters TSA, TCAM and TSAM.

The different potash applications produced significantly different yields of TCA which in turn produced a significant effect for TCAM. The higher potash levels of application produced more TSA but this was not regarded as a significant increase. The exchangeable soil potassium varied from 140 to 210 ppm, which is above the critical level where response for TSA is expected.

None of the interaction mean squares for NxK, AxN, AxK, or AxNxK was much, if any, larger than the corresponding error (b) mean squares for the five characters.

Table 7

Mean Yields for the Various Categories from the Experiment at Kekaha (Variety 37-1933, Spring Planting)

Category		Means For				
		TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 17 mos.		82.8	12.9	10.6	4.96	.627
23 "	a	103.4	14.5	15.2	4.54	.668
24 "		102.4	15.3	15.6	4.22	.641
Zero lbs. Nitrogen/A		86.5	14.4	12.5	4.11	.586
150 "	b	100.5	14.2	14.3	4.75	.670
300 "	c	101.2	14.1	14.4	4.85	.681
Zero lbs. Potash/A	b	89.6	14.3	12.9	4.26	.607
200 "	b	99.5	14.2	14.2	4.72	.664
400 "	b	98.1	14.2	14.0	4.69	.661
Age and Nitrogen - Level	N_1A_1	76.5	12.8	9.8	4.53	.580
	N_1A_2	93.6	14.8	13.8	4.11	.605
	N_1A_3	89.5	15.6	14.0	3.69	.573
	N_2A_1	81.9	12.8	10.3	4.85	.612
	N_2A_2 d	109.3	14.5	16.1	4.80	.708
	N_2A_3	111.8	15.2	16.9	4.60	.703
	N_3A_1	89.9	13.1	11.6	5.33	.688
	N_3A_2 e	111.0	14.3	16.3	4.88	.713
	N_3A_3	105.9	15.0	15.8	4.36	.653
General Mean		95.8	14.2	13.7	4.56	.644

a mean of 15 plots for TCA, TSA, TCAM and TSAM
b " " 17 " " " " " " "
c " " 16 " " " " " " "
d " " 5 " " " " " " "
e " " 4 " " " " " " "

Table 8

Analyses of Variance for Yield Characters from the Kekaha Experiment, Spring Planting

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	733.35	5.35	2.04	2.25	.0071
Age of Harvest - A	2	2679.61	27.41*	139.13**	2.15	.0078
Error (a)	2	311.89	1.13	2.23	1.20	.0081
Amounts of Nitrogen - N	2	1418.68**	.35	22.21**	3.02**	.0476**
Amounts of Potash - K	2	515.30*	.14	8.30	1.15*	.0184
N x K	4	137.29	.34	3.05	.40	.0074
A x N	4	128.41	.36	3.04	.23	.0061
A x K	4	81.93	.08	1.08	.17	.0022
A x N x K	8	174.14	.95	2.28	.42	.0061
Error (b)	21[a]	140.28	1.30	2.98	.29	.0066
Coefficient of Variation (%)		12.9	8.0	12.4	13.3	12.3

[a]Error (b) mean square for Y%C is associated with 24 degrees of freedom

* Observed F exceeds tabulated F at 5 per cent point
** Observed F exceeds tabulated F at 1 per cent point

Fall Planting:

The fall planting was made on October 13, 1952, or about five and one-half months after the spring planting at Kekaha. The three times and ages of harvest were:

Harvest	Date Harvested	Age in Months
A_1	4/20/54	18
A_2	8/9/54	22
A_3	10/18/54	24

The mean yields for various categories and the analyses of variance are presented in Tables 9 and 10, respectively.

The nitrogen levels significantly affected the yields for the five characters. All characters except Y%C increased with increasing amounts of nitrogen applied. For TCA, the 300-pound nitrogen application more than doubled the yield over the no-nitrogen plots. The increase of the 150-pound over the zero application was almost 100 per cent. For Y%C, the percentage of juices from the zero and 150-pound nitrogen plots were almost identical, whereas the 300-pound nitrogen plots resulted in a significant decrease relative to the other two nitrogen levels These results follow the same trends as those obtained for the spring planting, but to a more marked degree.

TCA and TSA were significantly affected by the different potash applications. The 200 and 400 pound applications gave significant increases in yield over the zero potash plots. The differences between 200 and 400 pound applications were not significant. There was a significant increase in TSA with both the 22- and 24-month harvests being significantly higher than the 18-month.

The only other significant effect found in the fall planting data is the AxN interaction for TCAM. The mean yields for the zero nitrogen plots (Table 9) increased with age of harvest. For the 150-pound nitrogen plots, A_2 gave the lowest yields, and A_3 was lower than A_1. This is a reversal of the results obtained for the zero nitrogen plot yields. The 300-pound nitrogen plots reacted somewhat similarly to the 150-pound nitrogen plots with regard to age differences. The change in trend by age for the zero nitrogen plots relative to the other plots gave rise to the significant A x N interaction mean square.

Table 9

Mean Yields for the Various Categories from the Experiment at Kekaha (Variety 37-1933, Fall Planting)

Category		Means For				
		TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 18 mos.		59.2	15.6	9.2	3.25	.507
22 "		70.6	16.2	11.4	3.22	.522
24 "		82.9	14.8	12.2	3.43	.504
Zero lbs. Nitrogen/A		43.8	15.9	6.9	2.01	.320
150 "		79.5	15.8	12.6	3.71	.588
300 "		89.3	15.0	13.3	4.17	.625
Zero lbs. Potash/A		68.4	15.2	10.4	3.19	.484
200 "		71.6	15.7	11.1	3.33	.518
400 "		72.6	15.8	11.4	3.37	.532
Age and Nitrogen Level	N_1A_1	30.3	15.7	4.7	1.66	.260
	N_1A_2	45.2	16.6	7.5	2.06	.343
	N_1A_3	56.1	15.3	8.6	2.31	.357
	N_2A_1	70.9	16.0	11.4	3.89	.627
	N_2A_2	78.3	16.2	12.7	3.57	.578
	N_2A_3	89.2	15.3	13.6	3.69	.560
	N_3A_1	76.3	15.1	11.6	4.19	.635
	N_3A_2	88.3	16.0	14.1	4.03	.645
	N_3A_3	103.4	13.9	14.4	4.28	.595
General Mean		70.9	15.6	10.9	3.30	.511

Table 10

Analyses of Variance for Yield Characters from the Kekaha Experiment, Fall Planting

Source of Variation	Degrees of Freedom	Mean Squares For				
		TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	143.73	.03	3.47	.2387	.0076
Age of Harvest	2	2532.28	8.93	42.28*	.2301	.0017
Error (a)	2	180.75	.63	1.76	.3141	.0032
Amounts of Nitrogen - N	2	10306.60**	4.01**	219.60**	23.2263**	.4991**
Amounts of Potash - K	2	86.69*	1.61	4.96**	.1655	.0109
N x K	4	5.66	1.08	1.71	.0183	.0038
A x N	4	42.02	.72	1.61	.3671**	.0131
A x K	4	37.15	.04	.56	.0586	.0007
A x N x K	8	43.12	.71	1.23	.0690	.0010
Error (b)	24	25.12	.69	.73	.0628	.0232
Coefficient of Variation (%)		8.6	5.3	8.3	8.8	9.6

Spring and Fall Planting Combined:

The spring and fall planting results from the Kekaha experiment were combined to determine which main effects might be considered as real and which effects gave consistent responses in the two plantings. The means of the age, nitrogen and potash main effects are given in Table 11, while those for various other combinations are listed in Tables 7 and 9. The spring-planting means are the general means in Table 7, while the fall-planting means are given in Table 9

The time-of-planting mean squares for TCA, TSA, TCAM and TSAM are significantly larger

than the error (a) mean squares. The spring-planting part of the experiment was in field 216, while the fall-planting part was in field 40. The observed difference might be due to time of planting or to location since the two effects are completely confounded with each other.

The age mean squares for TCA, Y%C, and for TSA are significantly larger than the error (b) mean squares. The A_1 harvests were lower than the A_2 and A_3 harvests for all three characters. The AxT interaction mean squares for Y%C and TSA are significantly larger than the error (b) mean squares. The A_3 harvest had the highest juices in the spring planting and the lowest in the fall planting. The A_1 harvest means for Y%C was significantly below the A_2 and A_3 means in the spring planting, while it was intermediate in the fall-planting part of the experiment. A part of this interaction could also be a location or field x age-of-harvest interaction. For TSA the A_1 and A_2 mean difference in the spring was more than twice that in the fall planting. A part, or all, of this difference may be explained by the fact that the A_1 harvest was at 17 months in spring planting and at 18 months in the fall planting. The difference in TCA for the A_1 harvests relative to the A_2 harvests was much smaller for the fall planting than for the spring planting. In the combined analysis, the nitrogen and potash levels apparently did not affect Y%C even though the N_3 treatment mean was lower than N_2 means and the K_c treatment mean was higher than the K_a and K_b means. However, both the potash and nitrogen treatments had considerable effect on the remaining four characters. For nitrogen, the N_3 means were somewhat larger than the N_2 means, and the N_2 means were considerably above the N_1 means for all four characters. The big increases were in the N_2 treatment means over the N_1 treatment means with a further increase being obtained for the N_3 treatment.

For potash treatments the K_c and K_b treatments gave almost identical results for the four characters, TCA, TSA, TCAM, TSAM. Both the 200 and 400- pound applications of potash gave increased yields over the K_a potash treatment for the above four characters.

The significant interaction of NxT for TCA, TSA, TCAM, and TSAM, is due to the differential response of the N_1 treatment relative to the N_2 and N_3 in the spring planting as compared to the fall planting. In the spring planting, the N_1 mean was 14.5 TCA lower than the N_2 mean, while in the fall planting, this difference was 35.7 TCA. This difference in yields for N_1 and N_2 also affected the characters TSA, TCAM and TSAM.

The only other significant mean squares are the NxAxT mean squares for TCAM and TSAM. For TCAM, this significance is apparently caused by the non-significant NxA interaction for the spring planting, and by the significance of this interaction in the fall planting. Most of the significance is due to the failure of the age-of-harvests to respond in the same pattern for the spring and fall plantings to the zero-nitrogen treatment. The TCAM means for the treatments N_1A_1, N_1A_2 and N_1A_3 decreased with age of harvest in the spring planting, while the reverse was true for the fall planting.

For TSAM, neither of the NxA mean squares was as large as the error mean squares (Tables 8 and 10). From Tables 7 and 9, it may be observed that the ages of harvest had a relatively uniform response pattern for the N_3 treatment. This was not the case for the N_1 and the N_2 treatments. In the spring planting and in the no-nitrogen treatment, the means for A_1, A_2 and A_3 were not greatly different; in the fall planting the A_1 mean was considerably below the other means. For the N_2 treatment, the A_1 mean was considerably below the A_2 and the A_3 means, while in the fall planting, the A_2 and A_3 means were somewhat below the A_1 mean. Such reversals of response give rise to significant interactions. Whether this is a real effect or a result of chance sampling fluctuations (it is expected that five per cent of the mean squares tested would be declared significant by chance alone) would have to be determined in light of biological theory and other experimental evidence.

Table 11

Means for Various Categories from the Experiment at Kekaha (Spring and Fall Plantings*)

Category		Means For TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest -	A_1	71.0	14.2	9.9	4.08	.567
	A_2	87.9	15.4	13.3	3.92	.595
	A_3	92.6	15.1	13.9	3.82	.573
Amount of Nitrogen -	N_1	65.2	15.1	9.7	3.06	.453
	N_2	90.4	15.0	13.5	4.24	.629
	N_3	95.8	14.6	13.9	4.51	.652
Amount of Potash -	K_a	79.5	14.8	11.7	3.74	.546
	K_b	86.0	14.9	12.7	4.04	.592
	K_c	85.9	15.0	12.7	4.04	.596
General Mean		83.8	14.9	12.4	3.94	.578

* The mean yields contain the estimated values obtained for the spring planting results. To be strictly correct, these should not have been included in the means and the method described by Snedecor (1946, Chapter 11) should have been used. However, these means will differ little, if any, from the correct ones.

Table 12

Analyses of Variance for Yield Characters from the Kekaha Experiment (Spring and Fall Plantings Combined)

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Time of Planting - T	1	18073.04*	49.07	217.88*	44.3008*	.4853*
Blks. in Time of Pltg.-error(a)	2	438.54	2.69	2.76	1.2397	.0074
Age of Harvest - A	2	4667.06**	12.51*	165.92**	.5841	.0080
A x T	2	504.83	23.83**	15.36*	1.7940	.0016
Error (b)	4	246.32	.88	1.99	.7574	.0057
Amounts of Nitrogen - N	2	9640.60**	2.92	190.55**	21.4716**	.4275**
Amounts of Potash - K	2	500.24**	.45	12.43**	1.0812**	.0279**
N x K	4	69.80	.26	1.47	.2128	.0084
N x T	2	2084.68**	1.44	51.27**	4.7790**	.1193**
K x T	2	101.75	1.30	.83	.2363	.0014
N x K x T	4	73.15	1.16	3.29	.2039	.0070
N x A	4	17.21	.78	.78	.1040	.0054
K x A	4	26.43	.06	.32	.0387	.0005
N x K x A	8	148.87	1.04	2.25	.3281	.0050
N x T x A	4	153.23	.30	3.86	.4622*	.0137*
K x T x A	4	92.65	.07	1.33	.1853	.0025
N x K x T x A	8	68.38	.62	1.25	.1801	.0021
Error (c)	45	78.81	.99	1.78	.1684	.0043
Coefficient of Variation (%)		11.5	6.6	10.8	11.9	11.4

* Observed F exceeds tabulated F at 5 per cent point
** Observed F exceeds tabulated F at 1 per cent point

LIHUE

Spring Planting:

The Lihue spring planting was made on 3/15/52. The three times and ages of harvest were:

Harvest	Date Harvested	Age in Months
A_1	9/15-17/54	18
A_2	1/19-20/54	22
A_3	3/15-17/54	24

The A_2 harvest was at 22 months instead of at 21 months, due to the off-grinding season at Lihue.

The mean yields and the analyses of variance for the five characters for the spring planting are presented in Tables 13 and 14, respectively. The characters TCAM and TSAM were affected by age of harvest, with the 18-month harvest being significantly higher than the 24-month harvest for both characters. The 22-month harvest was better than the 24-month harvest for TSAM. The fact that the lowest TCA was obtained for the 24-month harvest is somewhat out of line with what is usually expected. However, in this experiment, all of the fertilizer was purposely applied early and it is likely that if the nitrogen supply became deficient in the second year, there would be a lot of dead cane which would reduce the TCA yield.

The yields for all five characters were affected differentially by the different nitrogen treatments. For TCA, TSA, TCAM, and TSAM, the N_3 treatment gave significantly higher yields than the N_2 treatment, and the N_2 treatment was considerably above the N_1 treatment. For Y%C, the reverse situation was obtained, with the N_1 treatment being better than the N_2 treatment, and the N_2 treatment yielding higher juice percentages than the N_3 treatment. Despite the lower juices for the N_3 treatment, more TSA were obtained due to the greatly increased TCA.

The potash treatments had no effect on Y%C in this experiment, but did affect the yields for the other four characters. The pattern for the effect of potash on these characters was of the same nature as that obtained for the nitrogen treatments, with K_c giving higher yields than K_b, which in turn gave higher yields than the K_a treatment. The differences between potash treatments were not as large as those between the nitrogen treatments. Response to potash was expected since the level of exchangeable soil potassium at the start of the experiment was 78 ppm.

The only significant interaction is the AxN for Y%C. The apparent reason for the interaction is the large differences between the A_1, A_2, and A_3 means at the zero-nitrogen application. The relatively high juice percentages for the N_1A_2 and the N_1A_3 combinations account for the major part of the significance of the AxN-interaction mean square.

As a further aid in interpreting the results from the spring-planting part of the Lihue test, some of the comments made by Ronald Toyofuku, Director of Agricultural Research and Control at Lihue, on the harvest results as they came in for statistical analysis, are presented below:

Comments on A_1 ("A") Harvest: Plots receiving no nitrogen germinated satisfactorily but were slow in growth and of small stalk diameter. Even with high potash combination, cane was stunted and remained erect long after the nitrogen treated plots had lodged or gone down.

Response to potash treatment was not half as pronounced as to the nitrogen treatment although higher potash amounts produced stalks of larger diameter. The advance information obtained from periodic stalk census indicated response to potash as well as to nitrogen.

Under normal conditions, we would not have applied 300# N per acre within the first five months, and at 18 months of age we would have expected poor juice quality. However, due to the extremely dry months which preceded harvest, juices were satisfactory.

Comments on A_2 ("B") Harvest: 0# K20. There seems to be no continuation of cane growth for the zero potash plots since last September. Improvement in juice quality from cold and fairly dry December and January resulted in a net increase of one ton sugar per acre over the September yield.

200# K20. This amount of potash, except at 0# N, gave some additional cane tonnage, but with no improvement in juice quality.

400# K20. When 400 lbs. K20 were applied, cane tonnage was substantially increased regardless of whether or not the plots received any nitrogen, although a larger margin of gain was noted for higher N treatment. There was no juice improvement with added age. The 400# K20 plots maintained higher population and a greater number of larger-sized stalks throughout.

Nitrogen. As with zero potash, no further gain in cane tonnage was obtained by extending the age of the crop by another four months. Response to nitrogen treatment was tremendous, especially in plots where adequate potash was supplied. The difference in the N treatment comparisons was much more pronounced and the higher N plots had more stalks of larger diameter and less of small size. Rat damage and per cent dead cane increased in the higher nitrogen plots.

Comments on A_3 ("C") Harvest: It appears by these results that 200 lbs. potash per acre was insufficient to carry the load beyond 18 months of age. At 22 and 24 months, 400 lbs. potash per acre gave best yields.

Response to nitrogen was not as pronounced as at harvest at 22 months of age. The zero-nitrogen plots were clean and sound with very little dead cane. The nitrogen-fertilized plots had much more cane but were a bit trashier, had more dead cane largely attributable to rat and borer damages.

Again, high nitrogen and high potash combination gave highest sugar yields.

The "A" block harvested last September at 18 months is now manifesting severe potash deficiency symptoms. These symptoms become more pronounced with heavier applications of nitrogen. Evidently this lack of a balanced diet is more detrimental to the crop than when both nutrients are proportionately low.

Table 13

Mean Yields for the Various Categories from the Experiment at Lihue (Spring Planting, Variety 44-3098

Category		Means For				
		TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 18 Mos.		82.4	10.6	8.8	4.58	.487
22 "		87.9	11.1	9.6	3.97	.436
24 "		76.0	11.9	8.9	3.17	.373
Zero lbs. Nitrogen/A -	N_1	57.1	11.7	6.6	2.73	.312
150 "	N_2	88.7	11.2	9.9	4.21	.470
300 "	N_3	100.6	10.8	10.8	4.77	.513
Zero lbs. Potash/A -	K_a	74.4	11.2	8.2	3.54	.390
200 "	K_b	82.4	11.2	9.1	3.94	.434
400 "	K_c	89.5	11.2	10.0	4.24	.471
Age & Nitrogen Level	N_1A_1	62.3	10.4	6.5	3.46	.360
	N_1A_2	57.5	11.7	6.7	2.60	.300
	N_1A_3	51.4	12.9	6.6	2.14	.277
	N_2A_1	87.0	11.0	9.6	4.83	.533
	N_2A_2	96.9	11.0	10.6	4.38	.482
	N_2A_3	82.2	11.6	9.5	3.43	.395
	N_3A_1	97.9	10.4	10.2	5.44	.567
	N_3A_2	109.4	10.7	11.7	4.95	.527
	N_3A_3	94.5	11.3	10.7	3.94	.447
General Mean		82.1	11.2	9.1	3.91	.432

Table 14

Analyses of Variance for Yield Characters from the Lihue Experiment
Spring Planting

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	1173.21	.54	17.56*	2.6978	.0395*
Age of Harvest - A	2	639.30	7.51	3.95	8.9595*	.0586*
Error (a)	2	206.34	.77	.77	.4281	.0020
Amounts of Nitrogen - N	2	9107.28**	3.39**	89.47**	19.9994**	.2017**
Amounts of Potash - K	2	1019.61**	.03	13.69**	2.1858*	.0297**
N x K	4	28.81	.03	.32	.0694	.0008
A x N	4	121.34	1.59**	.91	.1499	.0021
A x K	4	132.37	.21	1.48	.2906	.0037
A x N x K	8	51.45	.35	.51	.1287	.0013
Error (b)	24	83.46	.24	1.17	.1876	.0025
Coefficient of Variation (%)		11.7	4.7	11.8	11.5	11.6

* Observed F exceeds tabulated F at the 5 per cent point
** Observed F exceeds tabulated F at the 1 per cent point

Fall Planting:

The fall planting at Lihue was made on 9/10/52, almost six months after the spring planting was started. The three times and ages of harvest were:

Harvest	Date Harvested	Age in Months
A_1	3/17-19/54	18
A_2	5/26-27/54	21
A_3	8/30-31/54	24

The interval between the A_1 and the A_2 harvests is about two and one-quarter months, while that between the A_2 and the A_3 harvests is slightly over three months.

The mean yields of the various categories for the five characters are given in Table 15, and the analyses of variance are presented in Table 16. As in the spring planting, the age of harvests differed with respect to TCAM and TSAM. The pattern was somewhat different in that the A_2 harvest gave the highest yields, whereas the A_1 harvest gave the highest yields in the spring planting. However, the A_3 harvest was lowest in both plantings. The lower cane tonnages at the A_3 harvests relative to the A_2 harvests for both plantings require further explanation. The A_3 harvest plots may have been on poorer areas, they may have had considerably more rat and borer damages, or they may have been overripe, resulting in more dead cane. There were more dead stalks in the 24-month harvest than in the earlier harvests.

The nitrogen-treatment picture for the fall planting closely parallels that for the spring planting. The juice percentages were more adversely affected by the nitrogen treatments in the fall planting than they were in the spring planting. This difference is reflected, to some extent, in the TSA and TSAM mean yields for the nitrogen treatments. For TCA and TCAM, the mean yields for the N_3 treatment were significantly above the N_2 treatment means, and the N_2 means were considerably above the N_1 means. For TSA and TSAM, both the N_2 and N_3 means were significantly above the N_1 means, but the N_3 means were not enough higher than the N_2 means to be considered significant. For Y%C, the N_3 mean was significantly lower than the N_2 mean which was significantly lower than the N_1 mean.

The K_b and K_c potash treatments, while not differing from each other, were significantly above the K_a treatment for TCA, TSA and TSAM, and probably for TCAM. The TCAM mean square is just below the required significance level. For Y%C, the 200 and 400 applications increased the juice percentages to some extent over the zero-potash application. The increase was not significant, but it does follow previous patterns of response for the various potash treatments. Exchangeable soil potassium levels at 55 ppm at the start of the experiment and 57 ppm at harvest indicate shortages of potash.

None of the interaction mean squares were large enough to be considered significant.

The following comments by Ronald Toyofuku are helpful in understanding the harvest results of the fall planting.

Comments on A_1 ("A") Harvest: A good stand of cane was obtained from the hand-planted 44-3098, but it wasn't long before the zero-nitrogen plots showed signs of yellowing first, then retarding in growth. Nitrogen supply ran out at 6 1/2 months of age for the zero plots, 10 months for the 150# N plots and at 12 1/2 months for the 300# N plots. At harvest the zero plots had very light cane tonnage. The stalks were sound but short and spindly.

There is no explanation at this time for the failure of the crop in responding to potash treatment in this test. The test is located in a low potash field where significant responses were obtained in two previous crops of 32-8560. Soil analysis in this test area ran 50 and 60 ppm. The zero potash plots registered per cent sheath K to be only one per cent throughout, the 200# K20 plots 1.7 per cent and the 400# K20 plots 2.25 per cent, but only up to 9 1/2 months of age.

Field notes taken at eight months of age showed potash deficiency symptoms but potash fertilization in combination with zero nitrogen showed no beneficial effects.

Comments on A_2 ("B") Harvest: Due to inclement weather prior to and during harvest, only a half to three-fourths burn was obtained. Furthermore, it was not possible to send a second fire through after cane was cut. Considerable mud went through the mill with each sample which was not washed.

At 20.5 months of age, Block "B" picked up several tons of cane over Block "A" harvested at 18.2 months. In spite of the wet trash, the juice quality was only slightly poorer.

At harvest, the zero-nitrogen plots were light in tonnage regardless of potash fertilization, whereas it was difficult to note any potash response. Marked response to potash was anticipated since up to eight months of age the per cent K in the zero plots was never above one per cent while the per cent K for 200 lbs. potash was 1.7 per cent and 400 lbs., 2.25 per cent.

Comments on A_3 ("C") Harvest: The harvest results of this Block "C" followed a pattern similar to that of Field 13 Hm Block "C". In both cases there was a definite increase in cane and sugar yields for the 20 1/2 months and 22 months over the 18 months or "A" blocks. However, when these 3098 blocks were harvested at 23.7 months and 24 months, there was a decided loss. Evidently under our Lihue conditions, optimum age for 3098 is in the neighborhood of 22 months with adequate fertilization early in the crop.

Although permanent Warfarin stations were set out during the last six months of the crop, rats raised havoc with this isolated patch of cane, thus contributing to reduced yields. Borers were very much in evidence. Damages were more severe in the heavy tonnage plots.

Spring and Fall Plantings Combined:

The mean yields for the spring and fall plantings combined are given in Table 17 for the age, nitrogen, and potash main effects. The mean yields for the spring and fall plantings are the general means in Tables 13 and 15, respectively. The interaction means of the other factors with time of planting may be obtained from Tables 13 and 15. Since none of the interactions among nitrogen, potash, and age of harvest was considered to be a real effect, the various means were not listed.

The analyses of variance for the combined results are presented in Table 18. The only character apparently affected by the time of planting and/or location is TCAM. This means also that TCA difference is approximately of the same magnitude as TCAM since the ages of harvest did not vary radically for the two times of planting.

The mean yields for TCA, TSA, TCAM, and TSAM for the three different harvests are considered to be different. The A_1 and A_3 harvests gave almost the same mean yields for TCA and TSA; the A_2 harvest means were significantly higher than the means for the other two harvests. For TCAM and TSAM, the A_3 harvest means were significantly below the A_1 and the A_2 means.

Table 15

Mean Yields for the Various Categories from the Experiment at Lihue (Fall Planting, Variety 44-3098)

Category		Means For			
	TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 18 Mos	81.7	11.2	8.9	4.48	.489
21 "	95.4	10.9	10.2	4.65	.499
24 "	86.8	10.6	9.0	3.67	.380
Zero lbs. Nitrogen/A - N_1	63.0	12.0	7.5	3.04	.365
150 " N_2	93.4	10.9	10.1	4.53	.491
300 " N_3	107.5	9.8	10.5	5.22	.512
Zero lbs. Potash/A - K_a	83.0	10.7	8.7	4.04	.423
200 " K_b	90.2	11.0	9.7	4.37	.471
400 " K_c	90.7	11.0	9.8	4.38	.474
Age & Nitrogen Level - N_1A_1	55.5	12.4	6.9	3.04	.378
N_1A_2	71.4	11.8	8.4	3.48	.412
N_1A_3	62.1	11.7	7.2	2.62	.305
N_2A_1	88.2	11.1	9.7	4.84	.532
N_2A_2	99.9	10.9	10.8	4.87	.527
N_2A_3	92.0	10.7	9.8	3.89	.413
N_3A_1	101.4	10.1	10.1	5.56	.557
N_3A_2	114.9	10.0	11.5	5.60	.558
N_3A_3	106.3	9.4	10.0	4.49	.422
General Mean	88.0	10.9	9.4	4.26	.456

Table 16

Analyses of Variance for Yield Characters from the Lihue Experiment Fall Planting

Source of Variation	Degrees of Freedom	Mean Squares For				
		TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	77.52	1.24	.01	.2153	.0000
Age of Harvest - A	2	868.31	1.68	9.79	4.9567*	.0783*
Error (a)	2	66.93	.87	1.54	.1518	.0031
Amounts of Nitrogen - N	2	9325.64**	21.46**	47.84**	22.0961**	.1137**
Amounts of Potash - K	2	340.29*	.51	7.08**	.6730	.0149*
N x K	4	51.07	.40	.63	.1048	.0014
N x A	4	7.17	.18	.14	.1927	.0017
K x A	4	141.26	.25	1.06	.2580	.0017
N x K x A	8	102.70	.92	1.19	.2543	.0029
Error (b)	24	80.26	.41	.95	.1990	.0023
Coefficient of Variation (%)		10.1	6.1	10.6	10.3	10.7

* Observed F exceeds tabulated F at 5 per cent point
** Observed F exceeds tabulated F at 1 per cent point

The AxT interaction for Y%C was significantly larger than the error (b) mean square. From the three harvest means in Table 13 and three in Table 15, it may be observed that the yields of juices of three harvests in the spring planting are in the reverse order to yields of juices in the fall planting. This is a case where there is no evidence of the presence of a main effect and yet there is an interaction of the main effect with another main effect. If no biological evidence is available to explain the deterioration of juice percentage with harvest in the fall planting, such as a large proportion of half-dead stalks, while there was an increase with age of harvest in the spring planting, then one must conclude that the significant interaction arose from chance sampling variations.

With regard to the effect of the different nitrogen applications, the N_3 treatment means were the highest, with both the N_3 and the N_2 means being significantly above the N_1 means for TCA, TSA, TCAM, and TSAM. For Y%C, the N_3 treatment was significantly below the N_2 and the N_1 means, with the N_1 mean being significantly above the N_2 mean.

In the combined analysis, the effect of different potash applications was evident on the characters TCA, TSA, TCAM, and TSAM. There was no apparent effect of potash applications on Y%C although the 200- and 400-pound levels had higher juices than did the K_a treatment. The pattern of the response is consistent with previous results, even though the mean square is not regarded as significantly different from the error (c) mean square. For TCA and TCAM, the K_b mean was significantly above the K_a mean. The K_c mean was almost enough above the K_b mean to be denoted as significant. For TSA and TSAM, the K_c mean is regarded as being greater than the K_b mean which is greater than the K_a mean.

The NxT interaction appears to be present for Y%C and for TSA. The differences among the three nitrogen treatments are much larger in the fall than in the spring planting (Tables 13 and 15). With regard to TSA, the NxT interaction is caused by the effect opposite to that causing the NxT interaction for Y%C. Here the differences among the nitrogen treatments are larger in the spring planting than in the fall planting. The fact that the TCA yields were so different for the two plantings completely overshadowed the relatively small difference in Y%C. However, the differences in Y%C were enough to cause the significance of the NxT interaction for TSA.

There is a possibility that a real NxKxA interaction does exist, and that this is not a chance sampling fluctuation. However, further study is needed, and until more evidence is available this result will be considered as a vagary of sampling.

The significance of the NxTxA interaction for Y%C is the result of obtaining a significant AxN interaction for the spring plant data and not for the fall plant data (Tables 14 and 16). There is a uniform response in the fall but not in the spring planting. (Tables 13 and 15)

Table 17

Mean Yields for the Various Categories from the Experiment at Lihue (Spring and Fall Plantings)

Category	Means For				
	TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - A_1	82.0	10.9	8.8	4.53	.488
A_2	91.7	11.0	9.9	4.31	.468
A_3	81.4	11.2	9.0	3.42	.376
Amount of Nitrogen - N_1	60.0	11.8	7.1	2.89	.339
N_2	91.0	11.0	10.0	4.37	.480
N_3	104.1	10.3	10.7	4.99	.513
Amount of Potash - K_a	78.7	10.9	8.5	3.79	.406
K_b	86.3	11.1	9.4	4.16	.453
K_c	90.1	11.1	10.0	4.31	.473
General Mean	85.0	11.0	9.3	4.09	.444

Table 18

Analyses of Variance for Yield Characters from the Lihue Experiment
Spring and Fall Plantings Combined

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Time of Planting - T	1	924.59	3.07	2.01	3.4562	.0157
Blks. in Time of Pltg-error(a)	2	625.37	.89	8.79	1.4566	.0198
Age of Harvest - A	2	1195.60*	1.09	13.05*	12.4559**	.1268**
A x T	2	312.01	8.10	.69	1.4604	.0101
Error (b)	4	136.63	.82	1.15	.2900	.0026
Amounts of Nitrogen - N	2	18421.32**	20.95**	133.86**	42.0479**	.3088**
Amounts of Potash - K	2	1215.50**	.38	19.24**	2.5438**	.0417**
N x K	4	17.46	.37	.42	.0278	.0011
N x T	2	11.60	3.90**	3.45*	.0476	.0066
K x T	2	144.40	.16	1.53	.3150	.0029
N x K x T	4	62.42	.25	.53	.1464	.0012
N x A	4	39.87	.61	.39	.1836	.0028
K x A	4	140.31	.33	1.25	.2360	.0022
N x K x A	8	80.18	.70*	1.05	.2047	.0026
N x T x A	4	88.64	1.15*	.67	.1589	.0010
K x T x A	4	133.32	.13	1.29	.3126	.0032
N x K x T x A	8	73.98	.58	.65	.1784	.0015
Error (c)	48	81.86	.32	1.06	.1933	.0024
Coefficient of Variation (%)		10.9	5.5	11.1	11.0	11.0

* Observed F exceeds tabulated F at 5 per cent level
** Observed F exceeds tabulated F at 1 per cent level

OAHU

Spring Planting:

The spring planting at Oahu Sugar Company was made on 4/9-12/52. The three times and ages of harvest were:

Harvest	Date Harvested	Age in Months
A_1	9/9/53	17
A_2	2/1-3/54	22
A_3	4/27-28/54	25

The interval between the A_1 and A_2 harvests is 4 3/4 months while that between the A_2 and the A_3 harvests is 2 5/6 months.

The mean yields for the various categories and characters are given in Table 19. The analyses of variance for these data are given in Table 20. The A_2 harvest was significantly above the A_3 harvest, and the A_3 harvest mean was significantly better than the A_1 harvest mean for both TCA and TSA. For TSAM, the A_2 harvest was significantly higher than the A_1 and A_3 harvest means. The latter two harvests yielded approximately the same amount of TSAM.

The 300-pound nitrogen application was significantly better than the N_2 treatment for TCA, TSA, TCAM, and TSAM. The 150-pound nitrogen treatment, in turn, yielded significantly more TCA, TSA, TCAM, and TSAM than did the N_1 treatment. Although there were no significant differences among the three nitrogen treatments for Y%C, the same pattern of response is obtained as in previous experiments in this group.

In this experiment, the three potash treatments did not appear to affect the yields for any of the five characters. The pattern of response for TCA is the same but the one for Y%C is reversed. From the comments made on the harvest results by L. C. Kerns, Director of Agricultural Research and Control at Oahu, it would appear that ample potash was available on the zero potash plots and, therefore, no response to potash would be obtained. The level of exchangeable potassium in the soil was 190 ppm.

In line with some of the other experiments, there would appear to be a real NxA interaction for TCA. One of the causes for the interaction would appear to be that the differences between the A_1 and A_2 harvests are much larger for the N_2 and the N_3 treatments than for the N_1 treatment. A further cause for the interaction is that the differences between the A_1 and the A_3 harvest means increased with the amount of nitrogen applied. Apparently, nitrogen applications tend to keep the sugar cane plants in a more vigorous growing condition. The higher the nitrogen level, the less dead cane at the A_3 harvest date and, consequently, the greater TCA at the last harvest date.

Table 19

Mean Yields for Various Categories from the Experiment at Oahu (Spring Planting, Variety 44-3098)

Category		Means For TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 17 Mos. -	A_1	70.1	11.2	7.8	4.13	.459
22 "	A_2	118.1	11.4	13.3	5.43	.612
25 "	A_3	93.4	11.8	11.0	3.80	.448
Zero pounds Nitrogen/A -	N_1	58.4	11.6	6.8	2.80	.323
150 "	N_2	103.4	11.5	11.9	4.91	.563
300 "	N_3	119.8	11.3	13.5	5.64	.633
Zero pounds Potash/A -	K_a	92.8	11.8	10.8	4.40	.507
150 "	K_b	93.0	11.5	10.5	4.42	.497
300 "	K_c	95.9	11.3	10.9	4.53	.515
Age and Nitrogen Level -	N_1A_1	48.6	11.1	5.4	2.86	.313
	N_1A_2	74.0	12.0	8.8	3.40	.405
	N_1A_3	52.8	11.7	6.2	2.15	.250
	N_2A_1	77.1	11.3	8.7	4.54	.512
	N_2A_2	132.9	11.3	14.9	6.10	.687
	N_2A_3	100.3	12.0	12.1	4.08	.492
	N_3A_1	84.7	11.2	9.4	4.99	.553
	N_3A_2	147.6	11.0	16.2	6.78	.743
	N_3A_3	127.2	11.7	14.8	5.17	.602
General Mean		93.9	11.5	10.7	4.45	.506

Table 20

Analyses of Variance for Yield Characters from the Oahu Experiment, Spring Planting

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	483.60	2.49	2.89	1.5134	.0086
Age of Harvest - A	2	10385.30*	1.70	137.37**	13.3381	.1505*
Error (a)	2	239.81	.82	1.31	.8782	.0046
Amount of Nitrogen - N	2	18182.08**	.48	221.68**	39.1986**	.4764**
Amount of Potash - K	2	56.50	.98	1.09	.0968	.0016
N x K	4	146.29	1.23	.68	.3577	.0020
N x A	4	809.66*	.66	9.09	.8127	.0068
K x A	4	44.45	.86	1.38	.0878	.0025
N x K x A	8	434.72	1.18	2.70	.8652	.0054
Error (b)	24	200.98	.84	3.31	.4144	.0065
Coefficient of Variation (%)		15.2	7.9	16.6	15.1	15.7

* Observed F exceeds tabulated F value at the 5 per cent level
** Observed F exceeds tabulated F value at the 1 per cent level

Fall Planting:

The fall planting at Oahu was made on 7/29-30/52. The three dates and ages of harvest were:

Harvest	Date Harvested	Age in Months
A_1	2/4-5/54	18
A_2	5/14-15/54	22
A_3	8/4-5/54	24

The interval between the A_1 and A_2 harvests was three and one-third months, while that between the A_2 and the A_3 harvests was two and two-thirds months.

The mean yields for the various yield characters are presented in Table 21, and the analyses of variance for the characters are given in Table 22. The 18-month harvest was significantly lower in TSA than the other two harvests. Lower Y%C and TCA contributed to the decreased TSA. The A_2 harvest mean was significantly higher than either the A_1 or the A_3 harvest means for TSAM.

The three nitrogen applications produced different yields with regard to TCA, TSA, TSAM, and TCAM. The order of yields for the nitrogen treatments was the same for all four characters, with the N_3 treatment producing the highest yields; these were followed by yields for the N_2 treatment with the N_1 treatment producing the lowest yields. The N_1 treatment means were significantly lower than the N_2 treatment means for all four characters. The N_2 treatment means were significantly lower than the N_3 treatment means for TCA and TCAM; for TSA and TSAM, the N_2 means were lower than the N_3 means, but not significantly so. For Y%C, the N_3 treatment again gave the lowest juice percentage which was not significant.

The different potash applications had no apparent effect on any of the characters. In line with the comments by L. C. Kerns, this was to be expected since there was ample potash in the soil.

The significant NxKxA interaction in this part of the experiment for TCA and for TCAM would indicate a different NxK interaction for each age. From the individual analyses on each age, it was observed that the NxK interaction mean square was less than the error mean square at the A_1 harvest, whereas it was significantly larger than the error mean square at the A_3 harvest. The A_2 harvest results were intermediate. Although this would explain the significance of the NxKxA mean square relative to the yield results, this probably is a result of sampling fluctuations.

Spring and Fall Planting Combined:

From the combined results for means (Table 23) and mean squares (Table 24), it would appear that the spring-planting, and/or location, means (Table 19) were significantly below that for the fall-planting means (Table 21) for both TSA and TSAM.

In the combined analyses of variance, the age-of-harvest mean squares are significantly larger than the error (b) mean squares for all five characters. The A_2 harvest means were equal to or greater than the A_1 and A_3 harvest means for all five characters. The A_1 means for TCA and TSA are significantly below the A_3 means. For TSAM, the A_2 mean was significantly above the A_1 and the A_3 harvest means.

The pattern for nitrogen response is the same as in previous experiments in that the means for TCA, TSA, TCAM and TSAM increased with the amount of nitrogen applied. The N_3 means for TCA, TSA, TCAM, and TSAM, were signifcantly above the N_2 means, which in turn were different from the N_1 means. The differences among the nitrogen levels for Y%C were not large enough to be regarded as different from what would ordinarily be obtained in sampling from a single population; the N_3 mean was again the lowest.

The different potash treatments had little or no effect on the mean differences for the five yield characters. Since there was sufficient potash available in the soil, no response to potash application would be expected.

The significance of the NxA interaction mean squares for TCA is partly caused by the increase

in the differences of the A_3 and the A_1 means with increasing amounts of nitrogen; a part of this interaction is caused by the increased differences between the A_2 and A_1 means at the N_2 and the N_3 treatments, relative to the N_1 treatment. For TSA, the NxA interaction is caused by the increased differences with increased nitrogen levels for the comparisons A_3 - A_1 and A_2 - A_1.

Table 21

Mean Yields for Various Categories from the Experiment at Oahu (Fall Planting, Variety 44-3098)

Category		Means For TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 18 Mos. -	A_1	89.4	11.2	9.9	4.91	.542
21 "	A_2	113.3	13.1	14.9	5.27	.691
24 "	A_3	104.5	12.8	13.3	4.32	.548
Zero pounds Nitrogen/A -	N_1	73.7	12.4	9.1	3.47	.428
150 "	N_2	110.5	12.8	14.1	5.22	.663
300 "	N_3	122.9	11.9	14.7	5.81	.689
Zero pounds Potash/A -	K_a	104.7	12.6	13.2	4.92	.616
200 "	K_b	100.0	12.3	12.2	4.73	.572
400 "	K_c	102.4	12.2	12.6	4.84	.593
Age and Nitrogen Level -	N_1A_1	61.8	11.5	7.1	3.40	.388
	N_1A_2	81.0	13.3	10.8	3.76	.500
	N_1A_3	78.5	12.4	9.6	3.24	.395
	N_2A_1	96.0	11.8	11.3	5.27	.620
	N_2A_2	125.5	12.9	16.2	5.84	.755
	N_2A_3	110.1	13.6	14.9	4.55	.615
	N_3A_1	110.5	10.3	11.3	6.07	.617
	N_3A_2	133.4	13.2	17.6	6.21	.818
	N_3A_3	124.7	12.2	15.3	5.16	.633
General Mean		102.4	12.4	12.7	4.83	.594

Table 22

Analyses of Variance for Yield Characters from the Oahu Experiment, Fall Planting

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	1614.86	5.42	6.54	3.6296	.0133
Age of Harvest - A	2	2625.93	19.06	116.80*	4.1607	.1288*
Error (a)	2	423.15	1.23	2.08	.9132	.0045
Amounts of Nitrogen - N	2	11758.45**	3.41	169.95**	26.7170**	.3739**
Amounts of Potash - K	2	102.54	.78	4.84	.1693	.0089
N x K	4	38.43	.94	1.82	.0740	.0038
N x A	4	71.63	1.95	2.90	.3563	.0039
K x A	4	138.84	1.13	3.68	.2493	.0076
N x K x A	8	446.66**	1.04	6.90	.8621*	.0132
Error (b)	24	108.08	1.24	3.31	.3005	.0073
Coefficient of Variation (%)		11.2	9.0	14.1	12.2	14.1

* Observed F exceeds tabulated F value at the 5 per cent level
** Observed F exceeds tabulated F value at the 1 per cent level

The significance of the NxKxA interactions for TCA and TCAM and of the NxKxTxA interaction for TCA is probably due to chance fluctuations. If, however, there were real interactions, it is suspected that they would be relatively small. For these data, the significance of the NxKxAxT interaction is caused by the significance of the NxKxA interaction for the fall planting and the non-significance of this interaction in the spring-planting part of the experiment.

Table 23

Mean Yields for Various Categories from the Experiment at Oahu (Spring and Fall Plantings Combined)

Category		Means For				
		TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest -	A_1	79.8	11.2	8.9	4.52	.501
	A_2	115.7	12.3	14.1	5.35	.651
	A_3	98.9	12.3	12.1	4.06	.498
Amount of Nitrogen -	N_1	66.1	12.0	8.0	3.13	.375
	N_2	107.0	12.2	13.0	5.06	.613
	N_3	121.3	11.6	14.1	5.73	.661
Amount of Potash -	K_a	98.8	12.2	12.0	4.66	.562
	K_b	96.5	11.8	11.3	4.58	.534
	K_c	99.2	11.8	11.8	4.69	.554
Age and Nitrogen Level -	N_1A_1	55.2	11.3	6.0	3.13	.351
	N_1A_2	77.5	12.7	9.4	3.58	.453
	N_1A_3	65.6	12.1	7.6	2.69	.323
	N_2A_1	86.5	11.5	9.6	4.90	.566
	N_2A_2	129.2	12.1	15.0	5.97	.721
	N_2A_3	105.2	12.8	13.0	4.32	.553
	N_3A_1	97.6	10.7	10.0	5.53	.585
	N_3A_2	140.5	12.1	16.3	6.49	.781
	N_3A_3	126.0	12.0	14.5	5.16	.618
General Mean		98.1	11.9	11.7	4.64	.550

Table 24

Analyses of Variance for Yield Characters from the Oahu Experiment, Spring and Fall Plantings Combined

Source of Variation	Degrees of Freedom	Mean Squares For				
		TCA	Y%C	TSA	TCAM	TSAM
Time of Planting - T	1	1962.73	20.89	102.28*	3.9369	.2054**
Blk. in Time of Pltg-error(a)	2	1049.23	3.96	4.72	2.5715	.0110
Age of Harvest - A	2	11656.18**	14.27*	253.01**	15.3732*	.2782**
A x T	2	1355.05	6.49	1.17	2.1256	.0011
Error (b)	4	331.48	1.03	1.69	.8957	.0045
Amounts of Nitrogen - N	2	29589.76**	2.91	388.22**	65.3187**	.8439**
Amounts of Potash - K	2	77.12	1.74	4.32	.1223	.0073
N x K	4	98.23	1.57	.64	.1824	.0012
N x T	2	350.86	.98	3.41	.5974	.0064
K x T	2	81.91	.02	1.61	.1438	.0032
N x K x T	4	86.49	.60	1.87	.2493	.0046
N x A	4	522.65*	1.46	9.65*	.5404	.0073
K x A	4	79.51	.69	2.60	.1585	.0051
N x K x A	8	548.23**	1.24	4.64	1.0355*	.0087
N x T x A	4	358.65	1.15	2.33	.6286	.0034
K x T x A	4	103.78	1.30	2.46	.1787	.0050
N x K x T x A	8	333.16*	.98	4.96	.6918	.0099
Error (b)	48	154.53	1.04	3.31	.3574	.0069
Coefficient of Variation (%)		13.2	8.6	15.3	13.6	14.9

* Observed F exceeds tabulated F values at the 5 per cent level
** Observed F exceeds tabulated F values at the 1 per cent level

OLAA

Spring Planting:

The three dates of harvesting and ages of harvest for the spring-planting part of the Olaa test, which was planted on 4/8-17/52, were:

Harvest	Date Harvested	Age in Months
A_1	10/6-7/53	18
A_2	2/1-3/54	22
A_3	6/12-18/54	26

The interval between the A_1 and the A_2 harvests is slightly less than four months, while that between the A_2 and the A_3 harvests is about four and one-half months.

The mean yields for the various categories are given in Table 25, and the analyses of variance for these data are presented in Table 26. The A_1 harvest means for TCA and TSA were significantly lower than the corresponding means for the later harvests.

The order of response for the three nitrogen treatments was the same as for the three potash treatments for all five characters. With regard to significance, the results for potash treatments were the same as for the nitrogen treatments for all characters except Y%C. The N_2 and N_3 treatments were significantly better than the N_1 treatment for all five characters, and the K_b and K_c treatments were significantly better than the K_a treatment for TCA, TSA, TCAM, and TSAM. The exchangeable potassium level in the soil in 1952 was 135 ppm and 70 ppm in 1954. With 50 per cent rock, this soil was critically deficient in potash.

The results for the nitrogen treatments for Y%C are the opposite of those obtained in previous experiments. The relatively low yields of TCA for all treatments may be related to the results from the nitrogen treatments for Y%C. Also, it was noted that phosphorus was below the tentatively established critical level in the plant tissue during the first year of growth. The level of available phosphorus in the soil was 26 ppm.

The significance of the AxN interaction for TSAM is caused by the differential results obtained for the three harvests on the zero nitrogen plots as compared to the results obtained on the 150- and 300-pound nitrogen plots. The A_3 harvest mean was the highest of the three harvest means on the N_1 plots, but it was the lowest of the three on the N_2 and the N_3 plots.

Fall Planting:

The fall planting at Olaa was started on 9/25/52 (Block I) and 10/7/52 (Block II). The three dates and ages of harvest were:

Harvest	Date Harvested: Block I	Date Harvested: Block II	Age in Months
A_1	3/10-11/54	4/26-28/54	18
A_2	6/23/54	7/13/54	21
A_3	10/12/54	10/13/54	26

The interval between the A_1 and the A_2 harvests is roughly three and one-half months in Block I and two and one-half months in Block II. The interval between the A_2 and A_3 harvests is approximately three and one-half months in Block I and three months in Block II. This experiment is the most variable of the six tests with regard to age at harvest for the various blocks at a specified harvest treatment.

The mean yields for the various categories are listed in Table 27. The analyses of variance for the yield characters from the fall planting part of the Olaa test are presented in Table 28. The A_1 harvest mean was significantly below the A_3 harvest mean for TCA. The different harvest dates had relatively little effect on the mean yields of the remaining characters.

Table 25

Mean Yields for the Various Categories from the Experiment at Olaa (Spring Planting, Variety 44-3098)

Category		Means For TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 18 Mos.,	A_1	42.1	12.6	5.3	2.37	.297
22 "	A_2	51.2	13.1	6.8	2.37	.312
26 "	A_3	54.6	12.4	6.8	2.09	.261
Zero pounds Nitrogen/A -	N_1	40.5	12.1	4.9	1.84	.223
150 "	N_2	52.0	12.8	6.7	2.42	.311
300 "	N_3	55.4	13.1	7.2	2.57	.335
Zero pounds Potash/A -	K_a	41.7	12.4	5.2	1.93	.239
200 "	K_b	52.2	12.7	6.7	2.41	.308
400 "	K_c	54.1	12.9	7.0	2.48	.321
Age and Nitrogen Level -	N_1A_1	29.4	12.0	3.5	1.65	.198
	N_1A_2	41.9	12.0	5.0	1.94	.230
	N_1A_3	50.3	12.3	6.2	1.93	.240
	N_2A_1	47.2	12.9	6.1	2.65	.340
	N_2A_2	54.3	13.6	7.4	2.51	.342
	N_2A_3	54.7	11.9	6.6	2.10	.252
	N_3A_1	49.8	12.8	6.3	2.80	.352
	N_3A_2	57.6	13.7	7.9	2.66	.363
	N_3A_3	58.8	12.9	7.5	2.26	.290
General Mean		49.3	12.7	6.3	2.28	.290

Table 26

Analyses of Variance for Yield Characters from the Olaa Experiment, Spring Planting

Source of Variation	Degree of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	.00	2.20	.46	.0118	.0005
Age of Harvest - A	2	752.48*	2.31	12.71*	.4492	.0125
Error (a)	2	22.59	1.75	.24	.0411	.0007
Amount of Nitrogen - N	2	1093.54**	4.93**	26.33*	2.6829**	.0629**
Amount of Potash - K	2	200.77**	1.16	17.40**	1.6127**	.0348**
N x K	4	76.52	.63	1.05	.1906	.0025
N x A	4	81.95	1.78	2.39	.3419*	.0078**
K x A	4	44.13	.58	.43	.0473	.0002
N x K x A	8	45.32	.97	.76	.1089	.0018
Error (b)	24	53.43	.65	.89	.0942	.0016
Coefficient of Variation (%)		14.5	6.8	14.6	13.2	13.1

* Observed F exceeds tabulated F values at the 5 per cent level
** Observed F exceeds tabulated F values at the 1 per cent level

The increase in the mean yields of TCA, TSA, TCAM, and TSAM was significantly related to the increase in the amount of nitrogen and in the amount of potash applied. The N_2 and the N_3 treatments produced significantly higher mean yields for the four characters than were obtained from the N_1 treatment, and the N_3 treatment was superior to the N_2 treatment with re-

gard to the mean yields of these characters. The K_b and K_c treatments, though not being significantly different in themselves, were superior to the K_a treatment for all four characters. The level of soil potassium varied from 200 to 325 ppm, but considering the fact that the sample contained up to 50 per cent rock, and since there were only five to six inches of soil over lava, response to potash was expected.

For Y%C, the higher nitrogen treatments again produced higher juices. This pattern of response follows that obtained in the spring planting but differs from that obtained in other experiments. Here again, the relatively low TCA may be related to this response pattern. Also, a possible deficiency of calcium and phosphorus in some of the plots may have been responsible for the response pattern obtained.

The NxK interaction mean square for TCA is significantly larger than the error (b) mean square. From the mean yields for the various treatments, we see that the differential response

Treatment	1a	1b	1c	2a	2b	2c	3a	3b	3c
TCA	35.8	41.0	46.1	42.6	53.4	53.7	50.6	57.6	61.8

of the potash treatments with 150 pounds of nitrogen relative to the N_1 and N_3 nitrogen treatments accounts for this. In fact, treatment 2b is the one that is out of line. Except for the fact that Olaa results are different, the significance of the NxK interaction probably would be ascribed to sampling fluctuations.

Table 27

Mean Yields for Various Categories from the Experiments at Olaa
(Fall Planting, Variety 44-3098)

Category		Means For				
		TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 18 Mos. -	A_1	42.1	12.7	5.4	2.32	.296
21 "	A_2	49.9	12.4	6.1	2.36	.291
24 "	A_3	55.5	11.4	6.2	2.28	.256
Zero pounds Nitrogen/A -	N_1	40.9	11.8	4.8	1.94	.227
150 "	N_2	49.9	12.3	6.1	2.35	.290
300 "	N_3	56.7	12.3	6.8	2.67	.324
Zero pounds Potash/A -	K_a	43.0	11.9	5.1	2.04	.243
200 "	K_b	50.7	12.4	6.2	2.39	.293
400 "	K_c	53.8	12.1	6.4	2.54	.306
Age and Nitrogen Level -	N_1A_1	38.1	12.2	4.7	2.10	.257
	N_1A_2	39.9	12.2	4.7	1.89	.223
	N_1A_3	44.9	11.2	4.9	1.84	.202
	N_2A_1	41.8	12.8	5.4	2.30	.297
	N_2A_2	52.1	12.4	6.4	2.47	.305
	N_2A_3	55.8	11.8	6.4	2.29	.268
	N_3A_1	46.4	13.0	6.1	2.56	.333
	N_3A_2	57.6	12.7	7.3	2.73	.343
	N_3A_3	66.0	11.2	7.2	2.71	.297
General Mean		49.2	12.1	5.9	2.32	.281

Spring and Fall Plantings Combined:

The combined results of the spring and fall plantings of the Olaa experiment are presented in Tables 28 and 30. The ages of harvest differed significantly for TCA and TSA. The A_1 harvest means were significantly lower than the corresponding means for the later harvests for both characters.

Table 28

Analyses of Variance for Yield Characters from the Olaa Experiment, Fall Planting

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	6536.20**	3.42	4.92	13.6203**	.1612*
Age of Harvest - A	2	815.77*	8.59	3.83	.0297	.0086
Error (a)	2	41.71	5.95	1.82	.1089	.0057
Amount of Nitrogen - N	2	1120.29**	1.22	19.92**	2.3865**	.0438**
Amount of Potash - K	2	560.99**	1.10	9.32**	1.2073**	.0200**
N x K	4	144.00*	.46	.56	.0424	.0016
N x A	4	73.89	.48	.65	.0945	.0010
K x A	4	48.91	.27	.26	.0412	.0002
N x K x A	8	24.46	.33	.37	.0716	.0010
Error (b)	24	40.09	.57	.60	.0952	.0015
Coefficient of Variation (%)		12.9	8.2	14.1	13.4	15.3

*Observed F exceeds tabulated F values at the 5 per cent level
** Observed F exceeds tabulated F values at the 1 per cent level

The mean yields for all five characters increased with increasing amounts of nitrogen with the higher amounts being significantly better than the lower amounts for all characters except Y%C. The N_2 and N_3 treatment means were almost equal, but both were significantly higher than the N_1 mean for Y%C.

The potash response was of the same pattern as the nitrogen response for TCA, TSA, TCAM, and TSAM, but the mean differences were not so pronounced. The K_b and K_c treatment means were significantly higher than the K_a treatment means. The K_c treatment means were higher than the K_b means for the four characters, but the difference was not large enough to be regarded as significant.

The only interaction mean squares which are significantly larger than the error (c) mean squares are the NxAxT interactions for TCA, TSA, TCAM, and TSAM. For TCA, the significance arises from the fact that the differences between age means in the spring planting decrease with the amount of nitrogen applied, and the differences between age means tend to increase with the amount of nitrogen applied in the fall planting. For TSA, the significance is caused by failure of the N_2A_3, N_1A_1, and N_1A_2combinations to respond in the same way in the spring planting as in the fall planting relative to the other treatment combinations. For TCAM, the mean for the N_1A_1 combination is lower than N_1A_2 and N_1A_3 means for the spring planting, while the reverse is true in the fall planting; for the N_2 treatment, the N_2A_3 mean is lower, relative to the other two means, in the spring planting than in the fall planting; for the N_3 treatment, the order of the age means in the spring planting is the reverse of the order for the fall planting. For TSAM, the reversal of the order of means on the N_1 treatment between the spring and the fall plantings appears to be the major cause for the significance of the NxAxT interaction. As stated previously, the time of planting effect is confounded with location and with differences in time of harvesting. Therefore, several explanations for the significance of the NxTxA interactions are available.

The lower yields of TCA for the Olaa experiment in comparison with the others poses several questions, the chief one being: what element or elements were limiting. The limiting factors might be sunlight, temperature, calcium, phosphorus, and/or a number of others. Certainly the fact that phosphorus levels in the plant were low for a number of months during the first year of growth does indicate that phosphorus could have been a limiting factor. Soil samples indicated that calcium might be a limiting factor (see harvesting results for Expt. 104(b) "B" series). The fact that nitrogen response was relatively low also indicates the presence of one or more limiting factors of growth.

Table 29

Mean Yields for the Various Categories from the Experiment at Olaa (Spring and Fall Plantings Combined)

Category		Means For			
	TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - A_1	42.1	12.6	5.3	2.34	.296
A_2	50.5	12.7	6.4	2.36	.301
A_3	55.1	11.9	6.5	2.19	.258
Amount of Nitrogen - N_1	40.7	11.9	4.8	1.89	.225
N_2	51.0	12.6	6.4	2.38	.301
N_3	56.0	12.7	7.0	2.62	.330
Amount of Potash - K_a	42.3	12.1	5.1	1.98	.241
K_b	51.4	12.6	6.4	2.40	.301
K_c	54.0	12.5	6.7	2.51	.313
Age and Nitrogen Level - N_1A_1	33.7	12.1	4.1	1.87	.228
N_1A_2	40.9	12.1	4.9	1.91	.227
N_1A_3	47.6	11.7	5.6	1.89	.221
N_2A_1	44.5	12.8	5.8	2.48	.318
N_2A_2	53.2	13.0	6.9	2.49	.323
N_2A_3	55.2	11.8	6.6	2.19	.260
N_3A_1	48.1	12.9	6.2	2.68	.342
N_3A_2	57.6	13.2	7.6	2.69	.353
N_3A_3	62.4	12.0	7.4	2.48	.293
General Mean	49.2	12.4	6.1	2.30	.285

Table 30

Analyses of Variance for Yield Characters from the Olaa Experiment, Spring and Fall Plantings Combined

Source of Variation	Degrees of Freedom	Mean Squares For				
		TCA	Y%C	TSA	TCAM	TSAM
Time of Planting - T	1	.63	7.32	3.45	.0561	.0022
Blk. in Time of Pltg-error (a)	2	3268.10	2.81	37.80	6.8161	.0809
Age of Harvest - A	2	1556.06**	7.88	15.22*	.3381	.0200
A x T	2	12.20	3.02	1.33	.1408	.0011
Error (b)	4	32.15	3.85	1.03	.0750	.0032
Amounts of Nitrogen - N	2	2185.70**	5.36**	45.86**	4.9884**	.1052**
Amounts of Potash - K	2	1343.67**	1.90	26.08**	2.7806**	.0537**
N x K	4	41.97	.99	.93	.0985	.0024
N x T	2	28.13	.79	.39	.0810	.0015
K x T	2	18.10	.37	.63	.0394	.0011
N x K x T	4	48.95	.10	.68	.1345	.0016
N x A	4	21.14	.71	1.03	.0853	.0037
K x A	4	56.33	.24	.56	.0440	.0003
N x K x A	8	25.23	.46	.73	.0579	.0018
N x T x A	4	134.70*	1.55	2.01*	.3511*	.0051*
K x T x A	4	23.43	.66	.08	.0445	.0001
N x K x T x A	8	44.54	.81	.40	.1225	.0011
Error (c)	48	46.76	.72	.74	.0945	.0015
Coefficient of Variation (%)		13.7	7.5	14.3	13.5	14.4

* Observed F exceeds tabulated F values at the 5 per cent level
** Observed F exceeds tabulated F values at the 1 per cent level

PIONEER

Spring Planting:

The spring planting at Pioneer Mill Company was on March 21, 1952, and the three dates and age of harvest were:

Harvest	Date Harvested	Agé in Months
A_1	9/23/53	18
A_2	1/12/54	22
A_3	4/13/54	25

The interval between the A_1 and A_2 harvests is about three and two-thirds months, while that between the A_2 and the A_3 harvests is about three months.

The mean yields of the spring planting for the various categories from the Pioneer experiment are presented in Table 31, and the analyses of variance are given in Table 32. The fact that the age-of-harvest mean differences for TCA and TCAM were denoted as significant is due to the unusually small error (a) mean squares obtained for these two characters; since the error (a) mean squares are so much smaller than the corresponding error (b) mean squares, the differences among age means are not considered unusually divergent as to differences obtained in sampling from a single homogeneous population.

The effects of nitrogen treatments in this experiment were large for TCA, TCAM, TSA, and TSAM. In all four cases, the N_2 treatment yields were almost twice that obtained from the N_1 treatment. A further significant increase of the N_3 treatment over the N_2 treatment was obtained for the same four characters. For Y%C, the pattern of response was similar to that obtained for Olaa; the N_2 and N_3 treatments gave significantly higher juices than were obtained from the N_1 plots. The relatively poor juices in the zero nitrogen plots could be due to a relatively large amount of dead cane.

None of the other effects were large enough to be considered as significant. The level of exchangeable potassium in the soil at the start of the experiment was 110 ppm, and since some additional potash was applied in the irrigation water, response to potash fertilizers was not expected.

Table 31

Mean Yields for the Various Categories from the Experiment at Pioneer (Spring Planting, Variety 37-1933)

Category		Means For TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 18 Mos. -	A_1	73.1	11.1	8.1	4.04	.450
22 "	A_2	84.2	10.4	8.9	3.93	.414
25 "	A_3	77.5	11.4	9.0	3.13	.362
Zero pounds of Nitrogen/A -	N_1	43.3	10.5	4.6	2.05	.217
150 "	N_2	85.0	11.1	9.4	4.02	.447
300 "	N_3	106.5	11.3	12.0	5.04	.563
Zero pounds of Potash/A -	K_a	80.4	11.0	8.9	3.82	.419
200 "	K_b	75.2	10.9	8.1	3.55	.384
400 "	K_c	79.2	11.2	9.0	3.74	.423
Age and Nitrogen Level -	N_1A_1	40.1	11.1	4.5	2.22	.250
	N_1A_2	46.5	9.9	4.6	2.17	.213
	N_1A_3	43.3	10.7	4.6	1.75	.187
	N_2A_1	81.1	11.3	9.2	4.49	.507
	N_2A_2	88.3	10.8	9.5	4.13	.447
	N_2A_3	85.6	11.2	9.6	3.46	.388
	N_3A_1	97.9	11.0	10.7	5.42	.593
	N_3A_2	117.7	10.6	12.5	5.50	.583
	N_3A_3	103.8	12.2	12.7	4.19	.512
General Mean		78.3	11.0	8.7	3.70	.409

Table 32

Analyses of Variance for Yield Characters from the Pioneer Experiment, Spring Planting

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	385.06**	.01	4.86	.8894**	.0112
Age of Harvest - A	2	562.38**	4.39	4.03	4.4520**	.0351
Error (a)	2	1.50	1.94	1.64	.0211	.0049
Amount of Nitrogen - N	2	1858.18**	2.66*	254.51**	41.6059**	.5589**
Amount of Potash - K	2	135.45	.52	3.92	.3420	.0081
N x K	4	37.09	1.55	2.35	.0783	.0058
N x A	4	99.18	1.35	1.86	.4165	.0020
K x A	4	28.46	.20	.21	.0866	.0003
N x K x A	8	128.63	.53	2.17	.2760	.0055
Error (b)	24	123.83	.72	1.92	.3331	.0045
Coefficient of Variation (%)		13.7	8.2	15.7	15.1	16.6

* Observed F exceeds tabulated F value at the 5 per cent level
** Observed F exceeds tabulated F value at the 1 per cent level

Fall Planting:

The fall planting at Pioneer was made on August 12, 1952, which is approximately four and three-quarter months after the spring planting. The ages and dates at harvest were:

Harvest	Date Harvested	Age in Months
A_1	2/24/54	18
A_2	5/24/54	21
A_3	8/11/54	24

The interval between the A_1 and A_2 harvests was three months, while that between the A_2 and A_3 harvests was approximately two and one-half months. With regard to the A_1 harvest, the area was burned and hand-cut on February 24, 1954, but due to the rains, the cane was not milled until March 1, 1954. The weather was cool; so it was presumed that the rate of deterioration was slow.

From the mean yields in Table 33 and the analyses of variance in Table 34, it may be noted that the age of harvest means are not exceedingly variable compared to the experimental variability. There is an apparent difference in age of harvest means for TSAM but the error (a) mean square is only about one-third of the error (b) mean square. Hence, the significance is questionable.

As in the spring-planting part of the experiment, the effect of the nitrogen treatments is relatively large, with the higher levels of nitrogen producing higher yields of TCA, TSA, TCAM, and TSAM than did the lower nitrogen levels. For Y%C, the N_2 and N_3 treatment means were approximately equal, but both were significantly higher than the N_1 treatment mean. The response obtained here is the same as for the spring-planting part of the experiment.

The differences in yields of TCA and TSA at the three levels of potash fertilization were not large enough to be considered significant. However, if the two degrees of freedom are split into individual degrees of freedom for the linear and quadratic effects of potash, the linear contrast is significantly different from the error (b) mean square. The level of exchangeable soil potassium at the start of the experiment was 53 ppm, which is below the established critical level. Hence, the conclusion is that higher potash levels of application result in higher yields in this part of the experiment, but not in the spring-planting part. None of the interaction mean squares were large enough to be considered as significantly different from the corresponding error (b) mean squares.

Table 33

Mean Yields for the Various Categories from the Pioneer Experiment, (Fall Planting, Variety 37-1933)

Category		Mean Squares For				
		TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - 18 Mos. -	A_1	83.3	12.7	10.8	4.52	.586
21 "	A_2	74.8	14.5	10.9	3.50	.509
24 "	A_3	90.1	12.6	11.6	3.76	.483
Zero pounds Nitrogen/A -	N_1	47.3	12.1	5.7	2.24	.268
150 "	N_2	88.5	13.9	12.3	4.22	.585
300 "	N_3	112.4	13.7	15.3	5.32	.726
Zero pounds Potash/A -	K_a	76.8	13.3	10.3	3.67	.492
200 "	K_b	83.9	13.0	11.1	3.96	.524
400 "	K_c	87.5	13.5	11.9	4.15	.563
Age and Nitrogen Level -	N_1A_1	46.8	11.2	5.6	2.22	.250
	N_1A_2	43.9	13.9	6.1	2.17	.213
	N_1A_3	51.2	11.3	5.8	1.75	.187
	N_2A_1	93.5	13.5	12.6	4.49	.507
	N_2A_2	80.1	15.0	12.0	4.13	.447
	N_2A_3	92.0	13.4	12.3	3.46	.388
	N_3A_1	109.5	13.5	14.7	5.42	.593
	N_3A_2	100.5	14.6	14.6	5.50	.583
	N_3A_3	127.2	13.2	16.7	4.19	.512
General Mean		82.7	13.3	11.1	3.93	.526

Table 34

Mean Yields for the Various Categories from the Pioneer Experiment, Fall Planting

Category	Degrees of Freedom	Mean Squares For				
		TCA	Y%C	TSA	TCAM	TSAM
Blocks	1	158.11	1.21	5.81	.2066	.0128
Age of Harvest - A	2	1057.09	19.92	3.27	5.1283	.0516*
Error (a)	2	430.55	5.89	1.17	.8240	.0020
Amount of Nitrogen - N	2	19533.00**	18.00**	440.62**	43.7383**	.9899**
Amount of Potash - K	2	533.93	1.05	11.70	1.0203	.0229
N x K	4	108.99	.62	1.64	.1974	.0034
N x A	4	226.88	1.26	3.60	.4901	.0111
K x A	4	332.32	.52	6.52	.6884	.0133
N x K x A	8	131.92	1.74	1.57	.3663	.0040
Error (b)	24	173.94	.94	2.89	.3763	.0062
Coefficient of Variation (%)		16.8	8.6	15.0	16.3	14.6

Spring and Fall Plantings Combined:

The combined results from the spring and fall plantings of the Pioneer experiment are given in Tables 35 and 36. It would appear that the spring-planting and/or location mean yields for Y%C, TSA, and TSAM were significantly lower than for the remainder of the experiment (Tables 31 and 33).

The age-of-harvest means for TCAM and TSAM were significantly different. The means yields for these two characters decreased with increasing age of harvest.

The significance of the AxT interaction for TCAM is apparently due to the large difference between the A_1 and A_2 means in the fall planting and the relatively small difference in the spring planting. The reverse situation holds for the mean differences for A_2 - A_3.

The most outstanding effect in the combined results is from nitrogen applications. The higher nitrogen levels give significant increases over the lower levels for TCA, TSA, TCAM, and TSAM. For Y%C, the N_2 and N_3 treatments gave significantly higher juices than the N_1 treatment.

The only apparent effect of potash applications was on TSA. The K_c treatment was significantly better than the K_a and K_b treatments. The K_c treatment produced the highest yields for all five characters.

From the nine treatment means for TSA, the significance of the NxK interaction would appear to be caused mostly by the high yield of the 3c treatment combination:

Treatment	1a	1b	1c	2a	2b	2c	3a	3b	3c
TSA	5.1	4.9	5.4	10.8	11.1	11.1	13.3	12.9	14.8

The significance of the NxT interactions for Y%C, TSA and TSAM is caused by the different results for the N_2 - N_1 differences in the spring and in the fall plantings. The differences N_2 - N_1 are larger for the fall planting.

None of the remaining interaction mean squares were large enough to be considered as significantly different from the corresponding error (c) mean squares.

Table 35

Mean Yields for the Various Categories from the Pioneer Experiment (Spring and Fall Plantings Combined)

Category		Means For				
		TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest -	A_1	78.2	11.9	9.5	4.28	.518
	A_2	79.5	12.5	9.9	3.71	.462
	A_3	83.8	12.0	10.3	3.44	.423
Amount of Nitrogen -	N_1	45.3	11.3	5.1	2.14	.242
	N_2	86.8	12.5	10.9	4.12	.516
	N_3	109.4	12.5	13.7	5.18	.644
Amount of Potash -	K_a	78.6	12.1	9.6	3.74	.456
	K_b	79.5	11.9	9.6	3.75	.454
	K_c	83.4	12.3	10.4	3.94	.493
Age and Nitrogen Level -	N_1A_1	43.5	11.1	4.8	2.38	.263
	N_1A_2	45.2	11.9	5.4	2.11	.249
	N_1A_3	47.2	11.0	5.2	1.94	.214
	N_2A_1	87.3	12.4	10.9	4.78	.595
	N_2A_2	84.2	12.9	10.7	3.93	.503
	N_2A_3	88.8	12.3	11.0	3.65	.451
	N_3A_1	103.7	12.2	12.7	5.68	.696
	N_3A_2	109.1	12.6	13.6	5.10	.633
	N_3A_3	115.5	12.7	14.7	4.75	.603
General Mean		80.5	12.1	9.9	3.81	.468

Table 36

Analyses of Variance for Yield Characters from the Pioneer Experiment (Spring and Fall Plantings Combined)

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSA
Time of Pltg.	1	541.37	141.69**	159.62**	1.3445	.3710
Blks. in Time of Plts. error (a)	2	271.59	.61	5.34	.5480	.0120
Age of Harvest - A	2	317.14	3.07	6.18	6.5997*	.0826
A x T	2	1302.33	21.25	1.12	2.9806*	.0040
Error (b)	4	216.03	3.92	1.40	.4226	.0035
Amount of Nitrogen - N	2	38099.99**	16.93**	682.32**	85.3220**	1.5178
Amount of Potash - K	2	229.05	1.50	8.02*	.4584	.0173
N x K	4	73.09	1.46	6.83*	.1496	.0080
N x T	2	14.86	3.72*	12.86**	.0222	.0310
K x T	2	440.33	.07	7.60	.9039	.0137
N x K x T	4	72.99	1.44	.55	.1261	.0012
N x A	4	104.32	.90	3.51	.4423	.0079
K x A	4	275.19	.11	3.78	.6232	.0080
N x K x A	8	59.66	1.65	.41	.1173	.0010
N x T x A	4	221.74	1.45	1.93	.4643	.0051
K x T x A	4	85.60	.62	2.95	.1518	.0028
N x K x T x A	8	200.89	.74	3.34	.5251	.0086
Error (c)	48	148.89	.83	2.40	.3547	.0054
Coefficient of Variation (%)		15.4	8.5	15.4	15.7	15.4

* Observed F exceeds tabulated F value at the 5 per cent level
** Observed F exceeds tabulated F value at the 1 per cent level

COMBINED ANALYSES FOR AMERICAN FACTORS PLANTATION TESTS

Spring Planting:

The results from the spring-planting parts of the six American Factors tests were combine to determine the persistence of main effects and interactions over all locations and the inte action of these effects and interactions with locations. In making tests of significance in co bined analyses, the usual assumptions about the homogeneity of components going into the various mean squares are necessary (Cochran and Cox, 1950). However, in the present an yses, the interest is more on sorting out large sources of variation than on making tests of significance. The usual F test procedure (Snedecor, 1946) is used as a guide in sorting out the relatively large sources of variation at a prescribed level.

The location means (Tables 1, 7, 13, 19, 25, and 31) do differ, and as expected, the mean squares for locations are relatively large. The error mean square for testing the location mean square is blocks within location (Table 38). The F tests were not made for location mean squares, since this would be rather pointless.

The age means over all plantations (Table 37) differ for all five characters. For TCA and TSA, the A_2 harvest means were the highest, the A_3 means were next in order, and the A_1 means were lowest. With age of harvest, the juice percentages increased, while TCAM decreased. The A_3 harvest mean was significantly below the A_2 and the A_1 means for TSAM. It should be remembered that the ages for the A_1, as well as for A_2 and A_3 harvest, differe from plantation to plantation.

The age means (Tables 1, 7, 13, 19, 25, and 31) did not respond the same at all locations, which gave rise to the significant AxL interaction mean squares for all five characters. Th ranking for TCA was A_3, A_2, and A_1 at Olaa; A_2, A_3, and A_1 at Kekaha, Lihue, Oahu, and Pioneer, and A_2, A_1, and A_3 at Grove Farm. For Y%C, the ranking of the harvest means was A_2 and A_1 at all plantations except Olaa and Pioneer where the ranking was A_3, A_1 and A_2. TSA, the rankings were A_3, A_2 and A_1 at Pioneer, Olaa, and Kekaha; A_2, A_3 and A_1 at Lih and Oahu; and A_2, A_1 and A_3 at Grove Farm. Likewise, reversals of rankings were found

TCAM and TSAM. This reversal of order, as well as of the relative differences of the harvest means, accounted for the significant AxL interaction mean squares. The facts that the ages for the prescribed harvests and that the season at which a given age was harvested differed from plantation to plantation probably account for a part of this interaction.

In the combined analyses, the mean squares for nitrogen applications represented the largest single source of variation for all characters except Y%C, which was apparently unaffected by the different nitrogen applications. The potash treatments resulted in the same response pattern as that obtained for the nitrogen treatments, except that the response was not so marked.

For TCA, the significance of the NxA interaction mean square is due to the increased differences for ages A_2 - A_1 and A_2 - A_3 as the nitrogen levels increased. For TSA, the difference A_2 - A_1 at the 300 nitrogen application is relatively large, and it would appear that this causes the significant interaction.

The nitrogen response at all plantations was not of the same magnitude and/or direction, thus giving rise to the significant NxL interaction mean squares for the five nitrogen characters. From the nitrogen level means at each location (Tables 1, 7, 13, 19, 25, and 31), the pattern of response for TCA, TCAM, TSA, and TSAM, is for increased yields with increased amounts of nitrogen. However, the relative differences between treatments N_3 and N_2 and N_2 and N_1 vary from test to test. For example, for TCA, the difference N_2 - N_1 at Oahu is 45.0 TCA, while this difference at Olaa is only 11.5 TCA. Such differential responses lead to the NxL interactions. For Y%C, the pattern of response is for juice percentage to decrease with increased amounts of nitrogen at Kekaha, Lihue, and Oahu. This pattern of response is completely reversed at Olaa and Pioneer, while at Grove Farm the order is N_2, N_1, and N_3. Such reversals-of-response patterns, as well as the change in magnitude of response (the nitrogen levels significantly affected Y%C at Lihue, Olaa, and Pioneer, but not at the other locations), account for the significance of the NxL interactions.

The significant KxL interaction mean squares for TCA, TSA, TCAM, and TSAM, arise from much the same factors, giving rise to significant NxL interactions. At some locations the potash effect was quite large, whereas at others it was nil. For TCA, potash treatments significantly affected yields at all locations except Oahu and Pioneer. For TSA, significant effects for potash treatments were indicated at Grove Farm, Lihue, and Olaa, but not at the other locations. Similar differential responses accounted for significant mean squares for TCAM and TSAM.

From the means for age and nitrogen levels for each location (Tables 7, 13, 19, 25, 31, and 37), the differential response of age yields to nitrogen treatments may be noted. At Oahu, the NxA mean square for TCA was significant, while no significance was found at the other locations. For Y%C, the NxA interaction mean square at Lihue was the only significant one found. However, this result alone was not enough to cause significance of the NxAxL interaction mean square for Y%C.

The KxAxL interaction mean squares for TCA and Y%C were surprisingly large in view of the fact that none of the individual mean squares were significant. From the age and level of potash means by location for TCA (Table 37), it may be noted that there is a small difference among age means at the different potash levels at Olaa, while a relatively large difference between age means at the different potash levels was obtained at Oahu. Apparently this differential response is caused by the relatively large AxL and the KxL interactions. For Y%C, the relatively large differences between age means at the different potash levels at Kekaha and the relatively small differences elsewhere, account for the significance of this interaction.

Table 37

Mean Yields for the Various Categories from the Combined Results for the Spring Planting of the Six American Factors Tests

Category		Mean Yields For TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest -	A_1	71.9	11.7	8.4	4.08	.477
	A_2	88.5	12.1	10.7	4.06	.487
	A_3	80.7	12.5	10.2	3.29	.415
Amount of Nitrogen -	N_1	56.9	12.1	7.0	2.70	.330
	N_2	87.1	12.2	10.6	4.12	.502
	N_3	97.1	12.1	11.6	4.60	.547
Amount of Potash -	K_a	75.6	12.1	9.2	3.59	.433
	K_b	81.4	12.1	9.8	3.86	.465
	K_c	84.0	12.1	10.2	3.98	.481
Age and Nitrogen Level -	N_1A_1	52.6	11.5	6.1	2.99	.346
	N_1A_2	61.4	12.1	7.6	2.81	.346
	N_1A_3	56.6	12.6	7.3	2.31	.299
	N_2A_1	77.6	12.0	9.3	4.39	.524
	N_2A_2	96.3	12.2	11.7	4.41	.534
	N_2A_3	87.3	12.4	10.9	3.56	.446
	N_3A_1	85.5	11.7	9.9	4.84	.560
	N_3A_2	107.9	12.0	12.7	4.95	.582
	N_3A_3	98.0	12.5	12.2	4.00	.499
Age and Nitrogen Level for Grove Farm	N_1A_1	58.6	11.7	6.8	3.21	.375
	N_1A_2	55.0	12.4	6.8	2.62	.322
	N_1A_3	52.5	12.4	6.5	2.18	.270
	N_2A_1	91.3	12.8	11.7	5.01	.642
	N_2A_2	94.9	12.2	11.5	4.52	.550
	N_2A_3	89.3	12.3	10.9	3.72	.455
	N_3A_1	92.7	12.0	11.1	5.09	.608
	N_3A_2	103.7	11.7	12.1	4.94	.577
	N_3A_3	98.1	12.1	11.8	4.09	.492
Age & Potash Level Grove Farm	K_aA_1	73.3	12.3	9.0	4.02	.497
	K_aA_2	75.0	12.1	8.9	3.57	.425
	K_aA_3	72.5	12.5	9.0	3.02	.377
	K_bA_1	83.3	12.1	10.2	4.57	.562
	K_bA_2	90.1	12.1	10.9	4.29	.518
	K_bA_3	83.0	12.3	10.1	3.46	.420
	K_cA_1	86.0	12.0	10.3	4.72	.567
	K_cA_2	88.4	12.0	10.6	4.21	.505
	K_cA_3	84.5	12.0	10.0	3.52	.420
Kekaha	K_aA_1	77.5	13.0	10.9	4.59	.592
	K_aA_2	95.2	14.6	14.1	4.18	.620
	K_aA_3	97.2	15.4	14.9	4.01	.612
	K_bA_1	83.6	12.9	10.7	4.96	.633
	K_bA_2	106.5	14.5	15.5	4.68	.682
	K_bA_3	109.5	15.1	16.4	4.51	.678
	K_cA_1	87.2	12.8	11.0	5.17	.655
	K_cA_2	108.6	14.4	16.0	4.54	.702
	K_cA_3	100.4	15.4	15.4	4.14	.633

Category		Mean Yields For TCA	Y%C	TSA	TCAM	TSAM
Lihue	K_aA_1	75.2	10.4	7.8	4.17	.432
	K_aA_2	78.3	11.3	8.8	3.54	.397
	K_aA_3	69.9	11.8	8.2	2.92	.342
	K_bA_1	87.5	10.7	9.4	4.86	.522
	K_bA_2	86.3	11.0	9.4	3.90	.423
	K_bA_3	73.4	11.9	8.6	3.06	.358
	K_cA_1	84.4	10.8	9.1	4.69	.507
	K_cA_2	99.2	11.0	10.8	4.48	.488
	K_cA_3	84.8	12.0	10.0	3.54	.418
Oahu	K_aA_1	68.8	11.1	7.7	4.05	.450
	K_aA_2	118.3	11.5	13.3	5.44	.612
	K_aA_3	91.2	12.6	11.4	3.70	.460
	K_bA_1	71.7	11.1	8.0	4.22	.468
	K_bA_2	116.6	11.5	13.3	5.36	.612
	K_bA_3	90.6	11.4	10.1	3.68	.610
	K_cA_1	69.7	11.3	7.9	4.11	.460
	K_cA_2	119.5	11.3	13.4	5.49	.613
	K_cA_3	98.6	11.5	11.6	4.01	.472
Olaa	K_aA_1	36.7	12.3	4.5	2.06	.253
	K_aA_2	43.6	12.7	5.5	2.02	.255
	K_aA_3	44.8	12.2	5.4	1.72	.210
	K_bA_1	45.4	12.5	5.6	2.55	.315
	K_bA_2	54.9	12.9	7.2	2.54	.333
	K_bA_3	56.3	12.8	7.2	2.15	.277
	K_cA_1	44.2	12.9	5.8	2.49	.322
	K_cA_2	55.2	13.6	7.5	2.55	.347
	K_cA_3	62.8	12.2	7.7	2.41	.295
Pioneer	K_aA_1	77.5	11.0	8.4	4.29	.465
	K_aA_2	88.4	10.4	9.2	4.04	.427
	K_aA_3	77.3	11.5	9.1	3.12	.367
	K_bA_1	68.3	11.2	7.7	3.78	.425
	K_bA_2	81.9	10.3	8.4	4.83	.393
	K_bA_3	75.3	11.0	8.3	3.04	.335
	K_cA_1	73.4	11.2	8.3	4.06	.460
	K_cA_2	84.2	10.6	9.1	3.93	.423
	K_cA_3	80.1	11.6	9.5	3.23	.385
General Mean		80.4	12.1	9.7	3.81	.460

Table 38

Analyses of Variance of Yield Characters for the Combined Results from the Spring Planting of the Six American Factors Tests

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Location - L	5	15391.43	78.35	334.93	36.6563	.7468
Blk. in Loc.	6	590.10	1.98	5.59	1.5348	.0135
Age - A	2	7492.67**	15.16**	150.64**	21.6833**	.1653**
A x L	10	1526.15**	5.65**	29.46**	2.6522**	.0366**
Error (a)	12	139.93	1.11	1.09	.4553	.0036
N	2	47424.06**	.54	632.80**	105.3947**	1.4098**
K	2	2022.93**	.16	29.57**	4.3575**	.0658**
N x K	4	178.10	1.35	3.78	.4240	.0089
N x A	4	449.51**	1.34	4.74*	.5191	.0053
K x A	4	43.96	.37	.67	.0414	.0015
N x K x A	8	176.59	.17	1.66	.3814	.0039
N x L	10	2114.31**	2.46**	24.06**	4.5758**	.0520**
K x L	10	282.55**	.60	4.91**	.6278**	.0105**
N x K x L	20	67.64	.55	1.20	.1673	.0026
N x A x L	20	176.15*	1.06	2.84	.3132	.0046
K x A x L	20	608.74**	3.40**	.98	.1363	.0017
N x K x A x L	40	137.12	.76	1.38	.2976	.0034
Error (b)	144	105.37	.70	1.79	.2300	.0038
Coefficient of Variation (%)		12.9	7.5	13.6	12.9	13.3

* Observed F exceeds tabulated F at the 5 per cent level
** Observed F exceeds tabulated F at the 1 per cent level

Fall Planting:

From the combined results for the fall-planting part of the six American Factors tests (Tables 39 and 40), by far the largest effects are nitrogen and location. The next largest effects are age of harvest and potash treatments. This is in line with expectations and with the results from the combined analyses for the spring plantings.

Age of harvest significantly affected all five characters but in different patterns: for TCA, the yields increased with age; for Y%C and TSAM, the A_2 harvests resulted in the highest yields, the A_1 means were second highest, and the A_3 means were the lowest; for TSA, the order of yields was A_2, A_3, and A_1; and for TCAM the means decreased with age.

The differential age x location response for TCA is caused by the change in magnitude and ranking of the harvest means at each location (Tables 3, 9, 15, 21, 27, and 33). At Grove Farm, Kekaha, and Olaa, the order of yields was A_3, A_2, and A_1; at Pioneer, the order of yields was A_3, A_1, and A_2; and at Lihue and Oahu, the order of yields was A_2, A_3, and A_1. Similar differential responses for the other characters account for the significance of the AxL interactions. It should be remembered that a part of the location effect is age-harvested and season-of-year.

The pattern of response for the nitrogen treatments for TCA, TSA, TCAM, and TSAM, is yield increase with the amount of nitrogen applied. The gain of the 300-pound treatment over the 150-pound level of application, although sizeable, was not as large as the gain between the zero and the 150-pound treatments. For Y%C, the highest juice percentages were obtained with the N_2 treatment, just as in the spring planting. However, in the fall planting, the N_3 treatment was lower than the N_1 treatment, whereas they were equal in the spring planting.

The yields of all five characters increased with increasing amounts of potash. Significant gains were obtained for all characters except Y%C where the juice percentages for the different treatments were almost equal. (They were equal in the spring planting). The differences K_b - K_a and K_c - K_b were almost equal in magnitude for all characters.

The significance of the NxA interaction for TCAM and TSAM is partly due to the greater rela-

tive difference between the A_3 and A_1 means for the N_2 treatment. Another contributing factor is the higher relative yields obtained for the A_2 harvests for the zero nitrogen level.

The nitrogen response was much greater at some locations than at others, thus giving rise to a significant NxL interaction for all five characters (see nitrogen means in Tables 3, 9, 15, 21, 27, and 33). For example, at Olaa, the differences for $N_2 - N_1$ were 9.0, 0.5, 1.3, 0.41, 0.063 for TCA, Y%C, TSA, TCAM and TSAM, respectively, while the corresponding differences at Oahu were 26.8, 0.4, 5.0, 1.75, and 0.235. The corresponding differences $N_3 - N_2$ at Olaa and Oahu were 6.8, 0.0, 0.7, 0.32, 0.013, and 12.4 - 0.9, 0.6, 0.59, 0.026, respectively. Such changes in relative response for each character gave rise to the significant NxL interactions.

No potash response was obtained at Olaa and Pioneer, while a sizeable response was obtained at the other four plantations. This differential response for TCA and TSA and for TCAM and TSAM from different potash treatments was the cause of the significant KxL interactions for these characters. The effect of potash treatments on juice percentages was relatively uniform from plantation to plantation.

The significance of the NxKxAxL interaction for TCA and TCAM is caused by the large response obtained at Oahu for this interaction. However, it is probably the result of sampling fluctuations.

Table 39

Mean Yields for the Various Categories from the Fall Planting of the Six American Factors Tests

Category			Means For		
	TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest - A_1	72.9	12.7	9.1	3.96	.492
A_2	82.5	13.2	10.8	3.86	.503
A_3	86.2	12.1	10.4	3.59	.431
Zero pounds Nitrogen/A - N_1	56.0	12.7	7.0	2.64	.331
150 " N_2	86.0	13.0	11.1	4.07	.523
300 " N_3	99.6	12.3	12.1	4.70	.572
Zero pounds Potash/A - K_a	76.8	12.5	9.5	3.63	.449
200 " K_b	80.6	12.7	10.1	3.80	.477
400 " K_c	84.2	12.7	10.6	3.97	.500
Age and Nitrogen Level - N_1A_1	49.1	12.7	6.1	2.66	.330
N_1A_2	57.5	13.4	7.6	2.69	.356
N_1A_3	61.5	12.1	7.4	2.56	.306
N_2A_1	80.0	13.0	10.3	4.34	.558
N_2A_2	88.3	13.3	11.7	4.13	.544
N_2A_3	89.5	12.6	11.3	3.72	.468
N_3A_1	89.5	12.3	10.8	4.87	.587
N_3A_2	101.7	13.0	13.1	4.76	.609
N_3A_3	107.6	11.6	12.5	4.47	.520
General Mean	80.5	12.7	10.1	3.80	.475

Spring and Fall Plantings Combined:

The combined results from the spring and fall plantings for the six American Factors tests are presented in Tables 41 and 42. The error mean squares for testing time of planting are the TxL mean squares. For all characters, the time-of-planting mean squares are not much, if any, larger than the TxL mean squares.

Different results for time of planting were obtained at the various locations for all characters. Such differential results, as well as the fact that the significance of time of planting, and/or

Table 40

Analyses of Variance of Yield Characters for the Combined Results from the Fall Planting of the Six American Factors Tests

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Location - L	5	18421.28	142.60	285.67	41.7591	.6074
Blk. in Loc.	6	1442.04	1.90	15.36	3.0427	.0331
Age - A	2	5125.12**	36.35**	87.20**	4.0047**	.1599**
A x L	10	785.66*	9.43*	18.99**	2.1340*	.0345*
Error (a)	12	269.62	2.53	1.98	.5409	.0042
N	2	53585.64**	12.36**	781.95**	120.3605**	1.7526**
K	2	1465.52**	2.23	32.69**	3.0486**	.0708**
N x K	4	31.68	1.68	1.41	.0776	.0026
N x A	4	171.86	1.12	2.24	.5938*	.0121*
K x A	4	155.44	.29	1.02	.2465	.0014
N x K x A	8	169.90	1.23	2.56	.4148	.0058
N x L	10	1265.81**	8.65**	37.99**	2.9102**	.0854**
K x L	10	205.10*	1.41	4.85**	.4159	.0098**
N x K x L	20	53.25	.53	1.25	.1168	.0029
N x A x L	20	92.67	.71	1.75	.2560	.0048
K x A x L	20	113.42	.50	2.41	.2321	.0050
N x K x A x L	40	159.94*	.75	2.16	.3494*	.0042
Error (b)	144	93.86	.75	1.75	.2214	.0040
Coefficient of Variation (%)		12.9	7.4	13.2	13.2	13.5

* Observed F exceeds tabulated F value at the 5 per cent level
** Observed F exceeds tabulated F value at the 1 per cent level

field, effects varied from test to test, accounted for the significant TxL interactions (Tables 6, 12, 18, 24, 30, and 36).

With regard to age of harvest, the A_2 harvest gave the highest yields for all characters except TCAM. The A_3 harvest was next highest for TCA, Y%C, and TSA, but was lowest for TCAM and TSAM. Since the fertilization practice followed was not the usual plantation practice, it should not be concluded that the best time to harvest is at 21 or 22 months; it is the best time if the practice used in the experiment was plantation practice.

The AxT interactions for TCA, Y%C and TCAM were significantly larger than the error (a) mean squares. For TCA, the means for the A_2 and A_3 harvests in the fall and spring plantings switch in order and in magnitude; for Y%C, the switch in order and in magnitude of the A_1 and the A_3 means accounts for the AxT interaction; for TCAM, the greater relative drop for the A_3 harvest in the spring planting accounts for the significant AxT interaction.

The relation of the differences between the age means for all five characters did not remain the same from location to location (Tables 5, 11, 17, 23, 29, and 35). For example, at Grove Farm, Kekaha, Olaa, and Pioneer, the A_3 harvest yielded the highest and the A_2 harvest second highest in TCA and TSA. However, at Lihue, the A_3 harvest was the lowest and the A_2 harvest was the highest; at Oahu, the A_2 harvest was highest and the A_1 harvest was lowest. Similar changes in response accounted for the AxL interaction for other characters.

Since the AxT interaction varies from location to location, a significant AxTxL interaction was obtained for all characters except TSAM. For example, a significant AxT interaction for Y%C was obtained at Grove Farm, Kekaha, and Lihue, but not at the other locations.

The nitrogen effect is relatively large with yields increasing with amount of nitrogen applied for all characters except Y%C. The N_2 treatment gave the highest juice percentages while the N_3 treatment gave the lowest.

The yields of all characters increased with the amount of potash applied, except that the K_b and K_c treatments resulted in the same average Y%C. The increases were not as striking as for nitrogen applications, but they were still fairly sizeable.

From the nitrogen means in Tables 37 and 39 for Y%C, it may be observed that there was almost no difference in mean juice percentage for the three nitrogen treatments in the spring planting, while there were relatively large differences among treatments in the fall planting.

The significance of the NxA interactions for TCA and TSA is caused by the increase in differences between treatments with an increase in the amount of nitrogen applied. For TCAM and TSAM, the differences for the A_1 and A_3 harvests were largest for the N_2 treatment and lowest for the N_1 treatment. These changes contributed to the significant NxA interactions.

The NxL interactions are relatively large for all five characters. From the nitrogen treatment means in Tables 5, 11, 17, 23, 29, and 35, it may be observed that the nitrogen responses vary with location. The interpretation here is much the same as those given for the combined spring plantings and the combined fall-planting analyses. Likewise, the significant KxL interactions for the combined results arise in much the same manner as described in the previous two sections.

A number of the remaining higher-ordered interaction mean squares are significantly larger than the corresponding error (b) mean squares. The explanation may be developed along lines similar to those given above. Although the lack of uniformity of response in the data can be used to explain these interactions, there still remains the question concerning the size of the true interaction. There is little doubt but that such interactions are present. However, any such interactions are probably relatively small and need not concern the sugar cane grower to any great extent.

A more serious question concerns the correct error mean square for each source of variation. If one wants merely to sort out relatively large sources of variation, then the procedure used in the combined analyses is sufficient. However, if tests of significance are being used to decide the presence or absence of an effect, and if the locations represent a sample of locations, then the interactions with locations will be the correct error mean squares for the effects.

Table 41

Mean Yields for the Various Categories from the Combined Results for the Spring and Fall Plantings of the Six American Factors Tests

Category		Means For				
		TCA	Y%C	TSA	TCAM	TSAM
Age of Harvest -	A_1	72.4	12.2	8.7	4.02	.484
	A_2	85.5	12.7	10.7	3.96	.495
	A_3	83.4	12.3	10.3	3.44	.423
Zero pounds Nitrogen/A -	N_1	56.5	12.4	7.0	2.67	.331
150 "	N_2	86.5	12.6	10.8	4.09	.513
300 "	N_3	98.4	12.2	11.9	4.65	.559
Zero pounds Potash/A -	K_a	76.2	12.3	9.3	3.61	.441
200 "	K_b	81.0	12.4	10.0	3.83	.471
400 "	K_c	84.1	12.4	10.4	3.97	.491
Age and Nitrogen Level -	N_1A_1	50.8	12.1	6.1	2.83	.338
	N_1A_2	59.5	12.8	7.6	2.75	.351
	N_1A_3	59.1	12.3	7.3	2.43	.303
	N_2A_1	78.8	12.5	9.8	4.37	.541
	N_2A_2	92.3	12.8	11.7	4.27	.539
	N_2A_3	88.4	12.5	11.1	3.64	.457
	N_3A_1	87.5	12.0	10.3	4.85	.573
	N_3A_2	104.8	12.5	12.9	4.85	.595
	N_3A_3	102.8	12.1	12.4	4.24	.510
General Mean		80.4	12.4	9.9	3.80	.468

Table 42

Analyses of Variance of Yield Characters for the Spring and Fall Plantings for the Six American Factors Tests

Source of Variation	Degrees of Freedom	Mean Squares For TCA	Y%C	TSA	TCAM	TSAM
Time of Pltg. - T	1	5.14	47.96	17.54	.0079	.0398
Pltn. - L	5	29146.83	185.29	525.19	67.5111	1.1458
T x L	5	4665.87**	35.67**	95.01**	10.9043**	.2084**
Blk. in T in L	12	1016.07**	1.94	10.48**	2.2887**	.0233**
Age of Harvest - A	2	10787.61**	13.82**	233.60**	21.9159**	.3251**
A x T	2	1830.18**	37.69**	3.27	3.7722**	.0001
A x L	10	1842.04**	7.27**	45.09**	3.4574**	.0669**
A x T x L	10	469.79*	7.82**	3.56*	1.3288*	.0041
Error (a)	24	204.77	1.82	1.54	.4981	.0039
N	2	100796.94**	8.20**	1410.95**	225.2881**	3.1530**
K	2	3430.19**	.84	62.08**	7.2435**	.1360**
N x K	4	125.94	1.56	2.75	.2556	.0060
N x T	2	212.77	4.70**	3.98	.4672	.0094
K x T	2	58.27	1.55	.13	.1626	.0006
N x K x T	4	83.84	1.47	2.44	.2460	.0055
N x A	4	426.95**	.89	5.51*	.7426**	.0141**
K x A	4	142.15	.53	.54	.1272	.0003
N x K x A	8	56.61	.90	.42	.0952	.0009
N x L	10	2872.30**	9.45**	47.61**	6.3509**	.1031**
K x L	10	284.11**	1.36	7.10**	.6111**	.0148**
N x K x L	20	39.91	.63	1.60	.0972	.0027
N x T x A	4	194.42	1.79*	1.37	.3703	.0034
K x T x A	4	57.25	.14	1.17	.1604	.0026
N x K x T x A	8	289.88**	.40	3.81*	.7011**	.0087*
N x T x L	10	507.82**	1.66*	14.40**	1.1351**	.0343**
K x T x L	10	203.56**	.65	2.67	.4325*	.0055
N x K x T x L	20	80.98	.46	.86	.2019	.0028
N x A x L	20	109.78	.83	2.48	.2215	.0042
K x A x L	20	93.60	.27	1.78	.2124	.0038
N x K x A x L	40	94.29	.57	.76	.3945**	.0043
N x T x A x L	20	159.03	.93	2.13	.3477*	.0051
K x T x A x L	20	80.69	.56	1.60	.1560	.0030
N x K x T x A x L	40	202.77**	.94	2.78*	.4619**	.0034
Error (b)	288	99.61	.72	1.77	.1956	.0039
Coefficient of Variation (%)		12.9	7.7	13.3	12.4	13.2

* Observed F exceeds tabulated F value at the 5 per cent level
** Observed F exceeds tabulated F value at the 1 per cent level

PATTERNS OF RESPONSE AND SIGNIFICANCE

As a somewhat less complicated and less efficient statistical procedure than those given in the Combined Analyses for American Factors Plantations, Tables 43 and 44 have been prepared. In Table 43, the various rankings of treatment means are listed for the spring planting, for the fall planting, and for the two plantings combined. If the fall and spring planting parts of the experiment are considered as separate experiments, there are 12 such experiments from which to observe a pattern of response for any given set of treatments. For age-of-harvest means, no consistent pattern holds, although the higher-numbered patterns predominate for all three characters. The spring and fall patterns are fairly consistent, except that for Y%C, they are reversed. This kind of differential response is the reason for the relatively large TxL and TxLxA interactions for these characters, and especially for Y%C.

The picture for nitrogen response is completely consistent for TCA and TSA. The No. 6 pattern predominates throughout. For Y%C, the response is not so strikingly uniform. Olaa and Pioneer are out of line with the remaining plantations. The reason for this is not clear. Probably, one associated fact is that the nitrogen response for TCA at Olaa was small, but this was not true at Pioneer.

The potash response for TCA is not so consistent as the nitrogen response. No response to potash was obtained at Oahu and Pioneer (Table 44). Except for these two experiments and the spring planting at Kekaha, there are consistent increases of TCA with increased potash levels. For Y%C, the response is associated with the higher-numbered patterns. Since no response to potash applications was found at Oahu for TCA, the response pattern obtained might just be a sampling fluctuation. However, there is still the response pattern for the spring planting at Grove Farm to explain. For TSA, the response pattern is fairly consistent, with No. 6 predominating. Except for the fall planting at Oahu, where no potash response was found, the 200- and 400-pound potash applications gave increased yields of TSA over the zero treatment.

The tendency for a given source of variation to remain relatively large or small over both plantings and over the six tests, may be noted from a table such as Table 44. For the characters TCA, Y%C, and TSA, the nitrogen response is the most consistent. The potash response is second to the nitrogen response in consistency of significance. These two sources of variation are followed by the age-of-harvest effect. An occasional significant mean square was found for the remaining mean squares; since these latter effects were of relatively infrequent significance, they might be considered either the result of sampling fluctuations or relatively small and unimportant.

With the aid of Tables 43 and 44, the significance of interactions in Tables 38, 40, and 42, may be interpreted with a minimum of difficulty. Such tables do not, however, consider the differences between means from the various categories. A change in differences of one category over the levels of another category could give rise to a significant interaction. For example, the nitrogen response pattern for TCA is consistent, but the relative magnitudes are not. This gives rise to the significant NxL interaction.

Table 43

Rankings of Treatment Means for the Age of Harvest

Plantation and Time of Planting		Pattern for Age of Harvest TCA	Y%C	TSA	Pattern for Amt. of Nitrogen TCA	Y%C	TSA	Pattern for Amount of Potash TCA	Y%C	TSA
Grove Farm -	Spring	3	6+	3	6	3	6	6	1	4
	Fall	6	1	3	6	1	6	6	4	6
	Combined	6	1	3	6	1+	6	6	4	6
Kekaha -	Spring	4	6	6	6	1	6	4	6-	4
	Fall	6	3	6	6	1	6	6	6	6
	Combined	6	4	6	6	1	6	4	6	6
Lihue -	Spring	4	6	4	6	1	6	6	±	6
	Fall	4	1	4	6	1	6	6	6-	6
	Combined	3	6	4	6	1	6	6	6-	6
Oahu -	Spring	4	6	4	6	1	6	6	1	5
	Fall	4	4	4	6	3	6	2	1	2
	Combined	4	6-	4	6	3	6	5	1-	2
Olaa -	Spring	6	5	6-	6	6	6	6	6	6
	Fall	6	1	6	6	6-	6	6	4	6
	Combined	6	3	6	6	6	6	6	4	6
Pioneer -	Spring	4	5	6	6	6	6	2	5	5
	Fall	5	3	6	6	4	6	6	5	6
	Combined	6	4	6	6	6-	6	6	5	5+
All 6 -	Spring	4	6	4	6	3*	6	6	±	6
	Fall	6	3	4	6	3	6	6	6-	6
	Combined	4	4	4	6	3	6	6	6-	6

Pattern	Order of Treatment Means	
1	1 > 2 > 3 or a > b > c	+ a = b or 1 = 2
2	1 > 3 > 2 or a > c > b	* a = c or 1 = 3
3	2 > 1 > 3 or b > a > c	- b = c or 2 = 3
4	2 > 3 > 1 or b > c > a	
5	3 > 1 > 2 or c > a > b	
6	3 > 2 > 1 or c > b > a	

Table 44

Significance of Various Effects by Plantation and Time of Planting

Source of Variation	Grove Farm t_1	Grove Farm t_2	Grove Farm t_1&t_2	Kekaha t_1	Kekaha t_2	Kekaha t_1&t_2	Lihue t_1	Lihue t_2	Lihue t_1&t_2	Oahu t_1	Oahu t_2	Oahu t_1&t_2	Olaa t_1	Olaa t_2	Olaa t_1&t_2	Pioneer t_1	Pioneer t_2	Pioneer t_1&t_2
TONS CANE PER ACRE																		
T*						x												
A**						xx			x	x		xx	x	x	xx	xx		
AxT																		
N	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
K	xx	x	xx	x	x	xx	xx	x	xx				xx	xx	xx			
NxK														x				
NxT						xx												
KxT																		
NxKxT			x															
NxA										x		x						
KxA																		
NxKxA											xx	xx						
NxAxT															x			
KxAxT																		
NxKxAxT												x						
YIELD PER CENT CANE																		
T*																		xx
A**		xx	xx	x		x						x						
AxT			xx			xx			x									
N		xx	xx		xx		xx	xx	xx				x		xx	x	xx	xx
K		x																
NxK																		
NxT			x						xx									x
KxT			xx															
NxKxT																		
NxA							xx											
KxA																		
NxKxA									x									
NxAxT									x									
KxAxT																		
NxKxAxT																		
TONS SUGAR PER ACRE																		
T*						x						x						xx
A**				xx	x	xx			x	xx	x	xx	x		x			
AxT						x												
N	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
K	xx	xx	xx		xx	xx	xx	xx	xx				xx	xx	xx			x
NxK																		x
NxT			x			xx			x									xx
KxT																		
NxKxT																		
NxA												x						
KxA																		
NxKxA																		
NxAxT															x			
KxAxT																		
NxKxAxT																		

*T - Time of planting
**A - Age of Harvest

THE OLOKELE TEST

As explained previously, the experimental design for the Olokele test differed in some respects from the six American Factors tests. This is the reason for presenting the analysis of the results in a separate section.

The crop was started on April 14, 1952, and was harvested on May 17, 1954, at about 25 months of age. The crop was irrigated and was variety 37-1933. As explained earlier, the N_1 treatment was 44 pounds of nitrogen per acre applied at time of planting. No reliable sample on Y%C was obtained for Plot 5 due to a "choking of the crusher". The yield for this plot was estimated by the ordinary missing plot formula for four blocks and nine treatments. Thus, the degrees of freedom for the error line in the analyses of variance will have 23 instead of 24 degrees of freedom for both Y%C and TSA.

The mean yields for nitrogen and potash treatments are given in Table 45, and the analyses of variance for TCA, Y%C, and TSA, are given in Table 46. The means and mean squares for TCAM and TSAM may be obtained by dividing the means and mean squares for TCA and TSA by 25 and 25^2, respectively. As with previous experiments, the yields of TCA and TSA increased with the amount of nitrogen applied. The yield differences between the N_1 and the N_2 treatments were larger than between N_3 and N_2. The highest juice percentages were associated with the N_2 treatment, with the Y%C for the N_3 being a close second. These results are somewhat similar to those obtained at Olaa and Pioneer. More dead cane was found in the lower tonnage plots. Since the low tonnage plots were the low nitrogen plots, starvation was undoubtedly a cause for the lower juice percentages.

No potash response was obtained in the Olokele test. The exchangeable soil potassium level of the check plots was 125 ppm, which is above the critical level. The NxK interaction was relatively small.

Table 45

Mean Yields for Various Categories from the Olokele Test
(Spring Planted, Variety 37-1933)

Category			Mean Yields For TCA	Y%C	TSA
44 pounds Nitrogen/A -		N_1	75.0	12.8	9.5
150	"	N_2	93.2	13.8(1)	12.5(1)
300	"	N_3	105.2	13.5	14.2
Zero pounds Potash/A -		K_a	90.4	13.5	12.1
200	"	K_b	91.7	13.2	12.1
400	"	K_c	91.4	13.5(1)	12.0(1)
General Mean			91.2	13.4	12.2

(1) Computed from 11 plots instead of 12 due to missing data for Y%C.

Table 46

Analyses of Variance for Yield Characters from the Olokele Experiment

Source of Variation	TCA D.F.	TCA Mean Sq.	Y%C D.F.	Y%C Mean Sq.	TSA D.F.	TSA Mean Sq.
Blocks	3	1131.64*	3	.50	3	23.06*
Amount of Nitrogen - N	2	2783.42**	2	3.11	2	69.20**
Amount of Potash - K	2	5.56	2	.33	2	.20
N x K	4	253.61	4	.82	4	3.83
Error	24	314.18	23	.94	23	5.38
Coefficient of Variation (%)		19.4		7.2		19.0

* Observed F exceeds tabulated F at the 5 per cent level
** Observed F exceeds tabulated F at the 1 per cent level

Literature Cited
Cochran, W.G. & G.M. Cox - Experimental Designs. Wiley, N. Y. 1950
Snedecor, G. W. - Stat. Methods, 4th Ed., Iowa State Coll. Press, Ames, 1946

APPENDIX D

A STATISTICAL STUDY OF THE N $\times$ X INTERACTION FOR YIELD CHARACTERS IN GROUP TEST No. 11

A STATISTICAL STUDY OF THE NxK INTERACTION FOR YIELD CHARACTERS IN GROUP TEST No. 11

W. T. Federer and R. K. Tanaka

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SUMMARY

An investigation of the results from 37 experiments was made for tons cane per acre (TCA) and yield per cent cane (Y%C) to study the relative sizes of the average error and nitrogen level x potash level (NxK) interaction mean squares. The average mean squares were nearly equal. The NxK interaction mean square was partitioned into four component parts to determine the relative sizes of the components. Only one component (the interaction of no nitrogen and some nitrogen with no potash and some potash) was of any appreciable size.

Since three of the four components of the NxK interaction could be considered independent estimates of the experimental error, a separate estimate of the experimental error was available. A comparison of the experimental error with the estimated experimental error was made to study the effect of the systematic arrangement of treatments. Since the mean values for the two mean squares were not appreciably different, it was concluded that the systematic placement of treatments did not invalidate the tests of significance.

INTRODUCTION

In a previous report, Special Release No. 116-A, May 1955, on the yields from the coordinated American Factors and Olokele Sugar Company experiment, it was noted that the NxK interaction mean squares were of about the same magnitude, on the average, as the error mean squares. Since it is the opinion of several investigators that there should be an NxK interaction for TCA and TSA, an investigation of the NxK mean square was carried out. The purposes of the investigation were to determine relative sizes of an orthogonal set of four individual-degrees-of-freedom-contrasts making up the interaction mean squares and the effect of the systematic plot arrangement on the error mean square.

The Method:

The four single-degrees-of-freedom-comparisons among the nine treatment means are:

Treatment					Comparison			
					$N'K_1$	$N'K_q$	N^oK^o	N^oK'
0 lbs. Nitrogen,		0 lbs. Potash		(N_1K_a)	0	0	4	0
0	"	200	"	(N_1K_b)	0	0	-2	2
0	"	400	"	(N_1K_c)	0	0	-2	-2
150	"	0	"	(N_2K_a)	+	+	-2	0
150	"	200	"	(N_2K_b)	0	-2	+	-
150	"	400	"	(N_2K_c)	-	+	+	+
300	"	0	"	(N_3K_a)	-	-	-2	0
300	"	200	"	(N_3K_b)	0	+2	+	-
300	"	400	"	(N_3K_c)	+	+	+	+

To illustrate the procedure, the yield results for TCA from the 18-month spring planting harvest at Grove Farm are used (the means are given in Table I).

Treatment	N_1K_a	N_1K_b	N_1K_c	N_2K_a	N_2K_b	N_2K_c	N_3K_a	N_3K_b	N_3K_c	Total
TCA (Total)	108.6	117.4	125.3	166.7	192.1	189.1	164.3	190.1	201.8	1455.4

Using the coefficients above, we find that the sum of squares for $N'K_1$ is

$$\frac{(166.7 - 189.1 - 164.3 + 201.8)^2}{2\ (4) = 8} = 28.50;$$

for $N'K_q$ is

$$\frac{(166.7 - 2\,(192.1) + 189.1 - 164.3 + 2\,(190.1) - 201.8)^2}{2\,(1 + 4 + 1 + 1 + 4 + 1) = 24} = 8.52;$$

for N^oK^o is

$$\frac{(4\,(108.6) - 2\,(117.4) - 2\,(125.3) - 2\,(166.7) + 192.1 + 189.1 - 2\,(164.3) + 190.1 + 201.8)^2}{2\,(16 + 4 + 4 + 4 + 1 + 1 + 4 + 1 + 1) = 72} = 50.17$$

for N^oK' is

$$\frac{(2\,(117.4) - 2\,(125.3) - 192.1 + 189.1 - 190.1 + 201.8)^2}{2\,(4 + 4 + 1 + 1 + 1 + 1) = 24} = 2.10$$

An alternative procedure for computing these interaction sums of squares is to use the following tables:

$N'K_l$ sum of squares

	K_a	K_c	Total
N_2	166.7	189.1	355.8
N_3	164.3	201.8	366.1
Total	331.0	390.9	721.9

$N'K_q$ sum of squares

	$2\,K_b$	$K_a + K_c$	Total
N_2	2 (192.1)	355.8	740.0
N_3	2 (190.1)	366.1	746.3
Total	764.4	721.9	1486.3

N^oK^o sum of squares

	$2\,K_a$	$K_b + K_c$	Total
$2\,N_1$	4 (108.6)	485.4	919.8
$N_2 + N_3$	662.0	773.1	1435.1
Total	1096.4	1258.5	2354.9

N^oK' sum of squares

	K_b	K_c	Total
$2\,N_1$	2 (117.4)	2 (125.3)	485.4
$N_2 + N_3$	382.2	390.9	773.1
Total	617.0	641.5	1258.5

Since the computation of the interaction sum of squares in a two-way classification is straightforward, the arithmetical details are not given here.

The $N'K_l$ mean square represents the interaction of the N_2 and N_3 levels of nitrogen with the linear effect of the potash levels. It would be suspected that this component would be second in order of magnitude among the four components if an NxK interaction were present in these data.

The $N'K_q$ component would be expected to be of about the same size as the error mean square. It is doubtful if this component would be of any appreciable magnitude even if an NxK interaction were present.

The N^oK^o component would be expected to be the largest component of these four. It represents the interaction of no nitrogen and some nitrogen with no potash and some potash. If this component is not significant, then it is doubtful if any of the others would be.

The N^oK' component might be thirdor fourth in order of magnitude among the four components. If potash requirements for sugar cane were considerably above the levels in these experiments, it might be expected that there would be a real N^oK' interaction. However, since this was not the case, this component probably represents an estimate of error variation.

The Data

The mean yields of the nine treatments for tons of cane per acre (TCA), juice percentage (Y%C), and tons of sugar per acre (TSA) for each age of harvest and time of planting are given

in Tables I, II and III.* In Tables IV, V, and VI, the error degrees of freedom and mean square are listed first. The next column contains the NxK interaction mean square with four degrees of freedom. The last four columns contain the mean squares for the four components of the NxK interaction discussed in the previous section.

In addition to the individual analyses for each harvest at a given time of planting, use can be made of the error and the NxK interaction mean square from the combined analyses for ages of harvest and from the combined analyses for ages of harvest and time of planting. These results are presented in Tables VII and VIII.

Significance of Mean Squares

A comparison of the NxK mean squares in Tables IV, V and VI, with the error mean squares for TCA and Y%C by means of Snedecor's F test, reveals that there are only three NxK mean squares which are large enough to attain significance at the five per cent level. There are a total of 74 comparisons and we would expect .05(74) = 3.7, or 3 to 4 of the mean squares to be significant on the average. The results agree well with expectation. A comparison of the weighted averages for the error and the NxK mean squares indicates a slightly larger NxK mean square for TCA (117.25 vs 127.91), identical error and NxK mean squares for Y%C (.75 vs .75), and a somewhat smaller NxK mean square for TSA (2.06 vs 1.77).

The average of the $N'K_l$, $N'K_q$ and N^oK' mean squares for TCA is slightly smaller than the error mean square, 108.15 versus 117.25. The average N^oK^o mean square is 60 per cent larger than the error mean square and 73 per cent larger than the average of the other three components. Considering the large number of degrees of freedom associated with these averages, the increase is significant at the five per cent level. The fact that the increase is significant should not obscure the fact that the size of the interaction is small.

For Y%C there are practically no differences among the average mean squares. The $N'K_l$ and $N'K_q$ mean squares are slightly smaller than the error, the N^oK^o and the N^oK' mean squares. This might be expected from biological theory and from the results on juice analyses in the report cited above for these tests. However, the difference, if present, is quite small.

For TSA, the NxK interaction mean square is 14 per cent smaller than the error mean square and the average of the $N'K_l$, $N'K_q$ and the N^oK' mean squares, 1.46, is 29 per cent below the error mean square. The latter decrease, 29 per cent, is significant at the five per cent level but the former, 14 per cent, is not. The N^oK^o mean square is significantly larger than the average of the other three components, $\frac{2.70}{1.46} = 1.85$, but not significantly larger than the error mean square.

From the combined analyses over ages of harvest given in the previously cited report, 12 mean squares are available for comparing the error, the NxK and the AxNxK mean squares. The AxNxK and NxK sums of squares for the combined results over ages of harvest is equal to the sum of the sums of squares for the NxK interaction for each harvest. In Table VII, the average error mean square is larger than the average NxK mean for all three characters; the difference between the two mean squares for TCA is the largest but the NxK mean square is not significantly smaller than the error mean square.

The average AxNxK mean squares in Table VII are somewhat larger than the error mean squares. This is probably a chance fluctuation since there is little evidence of an NxK interaction (Tables IV to VI) at any given age of harvest for either time of planting. Hence, an AxNxK interaction would not ordinarily be expected.

In Table VIII, the error NxK, and AxNxK mean squares presented are from the combined analysis for ages of harvest and times of planting. The differences follow much the same pattern as in Table VII. The difference between the NxK and error mean squares for TCA in Table VIII is larger than for the results in Table VII. However, here again, this is probably a chance fluctuation.

*The design was a systematically arranged split-split-plot design with the time of planting as the whole plot, the age of harvest as the split-plot, and the treatments in the split-split-plots. There were two replicates for the six experiments at the American Factors plantations. The Olokele design was a systematically arranged complete block with four replicates.

Effect of Systematic Arrangement on the Error Mean Square

The systematic arrangement used in these experiments was a variation of the pattern (nitrogen levels = 1, 2, 3; potash levels = a, b, c):

1a 2c 3b 1c 2b 3a 1b 2a 3c

With such an arrangement, two of the degrees of freedom for the NxK interaction mean square are completely confounded with groups of three plots. The error mean square for the NxK interaction mean square would usually be larger than the error mean square for main effects of nitrogen and potash. Thus, it would be expected that the pooled error mean square would be too large for the main effects and too small for the interaction. Also, the systematic pattern would tend to increase the error mean square for both main effects and interactions.

Since the $N'K_l$, $N'K_q$ and N^oK' components of the NxK mean square could be considered as individual estimates of the experimental error for the N^oK^o component, an independent estimate of the error mean square for the NxK interaction is available. The average of former three components is the estimate of the error and it may be compared with the average error mean; thus for the six American Factors experiments (Tables IV to V):

TCA:	100.05 versus (118.03 + 108.60 + 93.09)/3 =	106.57
Y%C:	.73 versus (.69 + .66 + .80)/3 =	.72
TSA:	2.06 versus (1.44 + 1.63 + 1.31)/3 =	1.46

The only appreciable difference in the two estimates of experimental error is for the character TSA. Whether the error from systematic arrangements unduly affects TSA would have to be determined from uniformity trial and other data.

From the above, it would appear that the systematic arrangement used had little effect on the error mean square for TCA and Y%C, but might have had on TSA.

COMMENTS

It is believed that a summarization of error and interaction mean squares for each type of experiment (e.g., variety x nitrogen level, potash level x phosphorus level, etc.) would be of considerable value to the experimenter. This is the way to determine whether or not an interaction is present and to prevent isolated cases of significance from being uppermost in the experimenter's mind. If the interaction mean squares are not partitioned into the individual components, the summarization can be effected with little effort from the "Harvesting Results" write-up on each experiment.

Only the mean values of the mean squares have been considered in this paper. An investigation of the frequency distribution of the mean squares could be made in a study of the effect of the systematic arrangement on the error variance. The frequency groups could then be compared with theoretical frequencies obtained from a chi-square distribution.

Table I

TCA FOR NINE TREATMENTS

Plantation	Planting	Age of Harvest Mos.	Treatments 1a	1b	1c	2a	2b	2c	3a	3b	3c
Grove Farm	Spring	18.2	54.3	58.7	62.7	83.4	96.1	94.6	82.2	95.1	100.9
		24.0	52.3	65.8	58.9	85.2	107.3	104.0	99.4	109.2	114.3
		24.0	51.5	57.1	48.9	78.1	90.7	99.3	88.1	101.2	105.2
	Fall	19.2	49.4	54.4	82.7	101.0	80.6	86.8	84.7	91.8	103.1
		21.9	69.0	58.1	64.8	87.9	90.9	103.7	102.2	117.2	126.5
		24.0	62.8	78.4	88.1	90.7	98.7	105.4	117.9	114.7	121.0
Lihue	Spring	18.0	53.5	70.0	63.3	74.4	94.6	92.0	97.6	98.0	98.1
		22.1	51.1	51.0	70.6	85.0	98.8	106.9	98.9	109.2	120.2
		24.0	48.6	46.3	59.5	75.9	76.8	94.0	85.3	97.0	101.1
	Fall	18.2	52.8	52.1	61.6	87.8	92.1	84.9	104.3	102.7	97.2
		20.5	69.8	79.9	64.6	100.1	96.1	103.7	100.7	123.4	120.7
		23.7	48.7	63.4	74.2	87.5	91.1	97.4	95.2	111.3	112.5
Kekaha	Spring	16.9	84.3	73.7	71.6	70.0	82.0	93.6	78.2	95.3	96.3
		22.8	90.4	89.7	100.7	96.0	116.7	121.0	103.4	119.9	110.4
		24.3	85.2	96.9	86.4	113.6	121.7	100.1	92.8	110.1	114.8
	Fall	18.2	29.3	29.8	31.8	71.0	70.0	71.7	73.7	79.6	75.7
		21.9	44.4	46.1	45.1	76.5	73.9	84.0	88.0	93.8	83.2
		24.2	50.5	58.1	59.7	83.5	93.6	90.7	98.4	99.9	111.8
Oahu	Spring	17.0	46.3	51.9	47.5	82.1	76.5	72.7	78.2	86.9	89.1
		21.8	68.0	62.8	91.3	140.8	147.0	111.0	146.3	140.1	156.3
		24.6	54.2	47.0	57.2	96.6	86.9	117.5	122.8	137.9	121.1
	Fall	18.2	58.8	63.9	62.6	91.2	94.8	102.0	116.0	111.1	104.3
		21.5	67.1	91.9	83.9	133.0	118.7	125.0	137.6	123.3	139.3
		24.2	104.8	53.9	76.9	113.6	106.1	110.7	120.6	136.1	117.5
Pioneer	Spring	18.1	49.0	34.2	37.3	88.2	75.1	80.1	95.3	95.6	103.0
		21.7	41.7	44.7	53.1	88.8	90.4	85.7	128.9	110.7	113.7
		24.8	49.1	39.1	41.6	88.7	83.4	84.9	94.1	103.4	113.8
	Fall	18.4	38.6	39.7	62.2	93.5	92.5	94.4	121.4	99.5	107.6
		21.4	44.0	48.6	39.1	73.8	87.6	78.9	89.3	104.7	107.6
		24.0	42.8	53.8	57.1	72.8	103.4	99.7	115.2	125.5	141.0
Olaa	Spring	17.8	26.1	32.9	29.2	46.6	46.4	48.5	37.5	57.0	55.0
		21.6	42.9	41.7	41.2	42.6	61.0	59.3	45.4	62.2	65.1
		26.1	39.5	53.2	58.2	47.6	52.3	64.1	47.2	63.3	66.1
	Fall	18.0	34.1	40.1	40.1	35.0	48.5	42.0	44.3	42.4	52.6
		21.1	34.6	36.9	48.1	45.8	52.6	57.9	52.1	59.0	61.8
		24.4	38.6	46.0	50.0	47.2	59.0	61.2	55.3	71.6	71.0
Olokele	Spring	25.1	81.9	77.5	65.7	91.4	91.0	97.4	98.0	106.6	111.2

Table II

Y%C FOR NINE TREATMENTS

Plantation	Planting	Age of Harvest Mos.	Treatments 1a	1b	1c	2a	2b	2c	3a	3b	3c
Grove Farm	Spring	18.2	11.9	11.4	11.8	12.8	12.9	12.7	12.3	-12.2	11.6
		24.0	12.7	12.2	12.3	11.8	12.4	12.3	11.8	11.8	11.5
		24.0	12.7	12.2	12.2	12.3	12.4	12.1	12.4	12.2	11.6
	Fall	19.2	13.0	13.1	12.9	11.3	13.6	13.5	11.1	12.3	12.2
		21.9	12.4	13.3	13.2	11.9	13.0	13.0	10.8	12.2	11.4
		24.0	11.1	10.8	10.4	10.3	11.0	10.7	9.3	10.5	9.4
Lihue	Spring	18.0	10.3	10.7	10.3	10.8	10.9	11.5	10.1	10.6	10.6
		22.1	11.8	11.9	11.3	11.1	10.8	11.1	11.0	10.4	10.6
		24.0	12.8	12.6	13.3	11.6	12.1	11.1	11.2	11.1	11.6
	Fall	18.2	12.5	12.9	12.0	10.0	11.2	12.0	9.8	10.3	10.1
		20.5	11.8	11.2	12.5	10.3	11.0	11.3	10.1	10.4	9.4
		23.7	11.9	11.9	11.3	11.1	10.5	10.5	8.8	9.4	9.9
Kekaha	Spring	16.9	12.9	12.4	13.0	12.2	13.3	12.8	13.8	12.9	12.6
		22.8	14.9	15.2	14.3	15.2	14.5	13.8	13.8	14.0	15.2
		24.3	15.7	15.4	15.8	15.0	15.3	15.4	15.5	14.5	15.0
	Fall	18.2	15.9	15.4	15.8	15.4	16.2	16.6	14.3	15.6	15.5
		21.9	15.9	17.6	16.3	16.1	15.3	17.2	15.8	16.2	16.1
		24.2	14.9	15.6	15.6	15.0	14.9	16.0	14.0	14.3	13.5
Oahu	Spring	17.0	11.1	10.8	11.5	11.0	11.6	11.3	11.4	11.0	11.1
		21.8	12.8	12.3	11.1	11.0	11.0	12.0	10.9	11.4	10.8
		24.6	13.0	12.0	10.2	12.6	11.7	11.8	12.1	10.6	12.6
	Fall	18.2	11.5	12.1	10.9	12.3	11.8	11.3	10.1	9.8	11.0
		21.5	13.8	13.0	13.2	13.6	11.3	13.9	13.4	13.3	12.9
		24.2	12.4	13.2	11.7	13.4	13.7	13.7	13.0	12.3	11.5
Pioneer	Spring	18.1	11.3	11.2	10.7	11.1	11.9	11.0	10.6	10.5	11.9
		21.7	9.7	9.8	10.1	10.4	11.4	10.8	11.1	9.7	11.1
		24.8	10.3	11.0	10.9	11.3	10.9	11.5	13.0	11.2	12.5
	Fall	18.4	13.3	9.5	10.8	13.1	13.8	13.6	13.0	13.4	14.1
		21.4	13.8	14.1	13.9	15.4	14.2	15.3	14.4	14.3	15.0
		24.0	10.7	11.3	11.8	13.4	13.1	13.7	13.0	13.4	13.2
Olaa	Spring	17.8	11.9	12.3	11.9	12.1	13.4	13.3	12.9	11.9	13.5
		21.6	11.5	11.0	13.4	13.1	13.7	14.0	13.6	14.1	13.4
		26.1	12.2	12.6	12.1	11.4	12.4	12.0	13.0	13.3	12.5
	Fall	18.0	12.3	12.0	12.4	12.8	13.0	12.6	12.6	13.4	13.2
		21.1	11.9	12.6	12.1	11.7	13.4	12.2	12.4	12.9	12.7
		24.4	11.3	10.9	11.3	10.9	12.2	12.3	11.4	11.4	10.8
Olokele	Spring	25.1	13.2	12.1	13.2	13.6	14.1	13.6	13.6	13.3	13.6

Table III

TSA FOR NINE TREATMENTS

Plantation	Planting	Age of Harvest Mos.	Treatments 1a	1b	1c	2a	2b	2c	3a	3b	3c
Grove Farm	Spring	18.2	6.5	6.7	7.4	10.7	12.4	12.0	10.1	11.6	11.7
		24.0	6.7	8.0	7.2	9.9	13.3	12.8	11.7	12.8	13.2
		24.0	6.6	6.9	5.9	9.6	11.2	12.0	10.9	12.3	12.2
	Fall	19.2	6.4	7.1	10.6	11.4	11.0	11.7	9.4	11.4	12.6
		21.9	8.5	7.7	8.5	10.4	11.9	13.4	11.1	14.2	14.4
		24.0	6.9	8.3	9.2	9.4	10.8	11.2	11.0	12.0	11.5
Lihue	Spring	18.0	5.5	7.5	6.5	8.0	10.3	10.6	9.9	10.4	10.4
		22.1	6.0	6.1	7.9	9.5	10.6	11.9	10.9	11.4	12.7
		24.0	6.2	5.8	7.9	8.8	9.3	10.4	9.6	10.8	11.7
	Fall	18.2	6.7	6.7	7.4	8.7	10.3	10.2	10.2	10.5	9.8
		20.5	8.2	9.1	8.1	10.3	10.6	11.7	10.2	12.8	11.4
		23.7	5.8	7.5	8.4	9.7	9.5	10.2	8.4	10.5	11.2
Kekaha	Spring	16.9	10.9	9.3	9.3	8.4	10.9	11.8	10.7	12.1	12.1
		22.8	14.0	13.6	14.3	14.5	16.9	17.8	14.6	16.9	16.8
		24.3	13.4	14.9	13.6	16.9	18.5	15.4	14.4	16.0	17.2
	Fall	18.2	4.7	4.6	5.0	11.1	11.3	11.9	10.6	12.4	11.7
		21.9	7.1	8.0	7.4	12.4	11.3	14.4	13.9	15.2	13.3
		24.2	7.5	9.0	9.3	12.5	13.7	14.5	13.8	14.3	15.1
Oahu	Spring	17.0	5.1	5.5	5.5	9.0	8.9	8.2	8.9	9.5	9.9
		21.8	8.6	7.8	10.1	15.4	16.1	13.3	16.0	16.0	16.8
		24.6	7.1	5.7	5.8	12.2	10.3	13.8	14.9	14.5	15.2
	Fall	18.2	6.7	7.7	6.9	11.2	11.2	11.5	11.6	10.8	11.4
		21.5	9.3	11.9	11.1	18.1	13.3	17.4	18.4	16.5	18.0
		24.2	12.9	7.2	8.7	15.1	14.5	15.1	15.7	16.8	13.6
Pioneer	Spring	18.1	5.5	4.0	4.0	9.8	9.0	8.8	10.0	10.0	12.2
		21.7	4.1	4.4	5.4	9.3	10.2	9.2	14.3	10.7	12.6
		24.8	5.0	4.3	4.6	10.0	9.1	9.8	12.3	11.6	14.3
	Fall	18.4	5.2	3.5	6.6	12.2	12.8	12.9	15.7	13.3	15.2
		21.4	6.1	6.9	5.5	11.4	12.5	12.1	12.9	15.0	16.1
		24.0	4.5	6.1	6.7	9.8	13.5	13.7	14.8	16.8	18.4
Olaa	Spring	17.8	3.1	4.0	3.5	5.6	6.2	6.5	4.8	6.7	7.4
		21.6	4.9	4.6	5.5	5.6	8.3	8.3	6.2	8.8	8.7
		26.1	4.9	6.8	7.0	5.4	6.5	7.9	6.1	8.3	8.3
	Fall	18.0	4.2	4.8	5.0	4.6	6.3	5.4	5.6	5.7	6.9
		21.1	4.0	4.5	5.7	5.3	7.0	6.9	6.5	7.6	7.8
		24.4	4.4	5.0	5.5	5.2	7.1	7.5	6.2	8.0	7.5
Olokele	Spring	25.1	10.6	9.3	8.6	12.5	12.8	12.3	13.3	14.2	15.1

Table IV

ERROR AND INTERACTION MEAN SQUARES - TCA

Plantation	Planting	Age of Harvest	Error d.f.	Error MS	NxK MS	Interactions $N'K_l$	$N'K_q$	N^oK^o	N^oK'
Grove Farm	Spring	18.2	8	6.39	22.32	28.50	8.52	50.17*	2.10
		24.0	8	69.26	38.77	7.60	70.73	35.42	41.34
		24.0	8	67.60	85.08	8.20	4.25	187.21	140.65
	Fall	19.2	8	159.67	318.60	528.13	83.63	408.50	254.15
		21.9	8	47.98	129.83	35.28	39.53	432.18*	12.33
		24.0	8	199.68	72.41	68.45	19.44	195.03	6.72
Lihue	Spring	18.0	8	62.11	65.42	147.06	84.00	10.66	19.99
		22.1	8	144.43	30.03	.18	6.83	45.76	67.33
		24.0	8	43.83	37.47	2.42	95.20	47.86	4.42
	Fall	18.2	8	90.06	54.34	9.03	9.50	30.81	168.01
		20.5	8	101.06	158.23	134.48	228.17	59.04	211.23
		23.7	8	49.68	43.91	27.75	51.92	62.35	33.61
Kekaha	Spring	16.9	8	69.78	217.04	15.13	42.14	764.40*	46.48
		22.8	5	42.33	97.01	163.81	.81	100.58	122.85
		24.3	8	271.99	171.52	630.13	49.31	3.78	2.87
	Fall	18.2	8	41.64	8.36	.85	26.04	.14	6.41
		21.9	8	14.92	54.27	69.62	147.01*	.01	.45
		24.2	8	18.52	29.26	19.53	91.65	.14	5.70
Oahu	Spring	17.0	8	69.83	57.48	205.03	11.90	4.11	8.88
		21.8	8	253.66	660.34	790.03	696.61	174.22	980.48
		24.6	8	279.44	297.92	256.51	867.61	60.50	7.04
	Fall	18.2	8	83.38	70.27	252.00	5.13	22.45	1.50
		21.5	8	124.66	269.87	47.04	15.68	773.55*	243.21
		24.2	8	116.21	591.61*	.01	354.97	1412.46**	599.00
Pioneer	Spring	18.1	8	229.50	59.28	124.03	19.62	87.34	6.10
		21.7	8	111.93	120.63	73.81	125.58	225.78	57.35
		24.8	8	30.08	114.44	276.12*	5.42	168.06*	8.17
	Fall	18.4	8	163.24	208.42	107.31	121.95	401.39	203.00
		21.4	8	50.06	72.54	86.46	16.84	157.83	29.04
		24.0	8	308.53	91.87	[illegible].72	260.04	102.48	4.25
Olaa	Spring	17.8	8	21.10	61.13	121.68*	93.62	19.95	9.25
		21.6	8	17.07	86.15*	4.35	6.30	333.25**	.70
		26.1	8	122.13	19.88	2.76	69.02	4.21	3.53
	Fall	18.0	8	39.83	43.70	.78	171.20	.48	2.34
		21.1	8	34.35	9.77	2.76	1.09	.91	34.32
		24.0	8	46.08	9.84	1.45	8.40	22.89	6.61
			Avg.	100.06	124.42	118.03	108.60	177.94	93.09
Olokele	Spring	25.1	24	314.18	253.61	51.48	38.70	520.60	403.68
		d.f.		309	148	37	37	37	37
		Wgtd. Avg.		117.25	127.91	116.23	106.72	187.20	101.49

Table V

ERROR AND INTERACTION MEAN SQUARES - Y%C

Plantation	Planting	Age of Harvest	Error d.f.	Error MS	NxK MS	Interactions N'K1	N'Kq	N°K°	N°K'
Grove Farm	Spring	18.2	8	.36	.14	.12	.01	.01	.40
		24.0	8	.56	.17	.28	.01	.33	.05
		24.0	8	.40	.10	.21	.00	.02	.15
	Fall	19.2	8	.40	.89	.66	.22	2.65*	.01
		21.9	8	.33	.11	.15	.18	.03	.06
		24.0	8	1.25	.36	.03	.26	1.05	.07
Lihue	Spring	18.0	8	.22	.14	.03	.19	.05	.30
		22.1	8	.28	.15	.10	.01	.03	.45
		24.0	8	.21	.45	.36	.70	.01	.70
	Fall	18.2	8	.51	.91	1.53	.00	1.10	1.00
		20.5	8	.50	.81	1.45	.14	.04	1.60
		23.7	8	.22	.54	1.45*	.08	.13	.48
Kekaha	Spring	16.9	8	2.53	.79	1.62	.88	.02	.64
		22.8	8	.85	1.23	3.92	.17	.00	.81
		24.3	8	.51	.23	.45	.45	.02	.01
	Fall	18.2	8	.31	.51	.00	.18	1.81*	.03
		21.9	8	.91	1.40	.32	1.71	.47	3.08
		24.2	8	.85	.60	1.20	.92	.24	.02
Oahu	Spring	17.0	8	.41	.26	.15	.35	.00	.45
		21.8	8	.53	1.18	.72	.81	1.87	1.31
		24.6	8	1.57	2.18	.91	1.00	1.39	5.42
	Fall	18.2	8	.58	.96	1.80	.38	.07	1.60
		21.5	8	2.47	1.41	.36	4.77	.01	.48
		24.2	8	.67	.66	1.53	.01	.15	.92
Pioneer	Spring	18.1	8	.54	.95	1.13	1.71	.62	.35
		21.7	8	.80	.84	.04	3.23	.05	.02
		24.8	8	.80	.82	.24	.67	1.59	.77
	Fall	18.4	8	1.99	3.48	.21	.26	12.75*	.70
		21.4	8	.52	.40	.21	.40	.13	.85
		24.0	8	.32	.21	.01	.28	.50	.06
Olaa	Spring	17.8	8	.99	1.03	.15	2.87	.13	.96
		21.6	8	.18	1.32**	.72	.17	.05	4.33**
		26.1	8	.80	.17	.60	.02	.06	.01
	Fall	18.0	8	.63	.63	.32	.03	.18	.43
		21.1	8	.23	.22	.02	.74	.09	.03
		24.0	8	1.11	.67	1.90	.05	.44	.28
			Avg.	.73	.75	.69	.66	.78	.80
Olokele	Spring	25.1	23	.94	.82	.00	.78	.60	1.88
		d.f.		311	148	37	37	37	37
		Wgtd. Avg.		.75	.75	.67	.67	.78	.83

Table VI

ERROR AND INTERACTION MEAN SQUARES - TSA

Plantation	Planting	Age of Harvest	Error d.f.	Error MS	NxK MS	$N'K_l$	Interaction $N'K_q$	N^oK^o	N^oK'
Grove Farm	Spring	18.2	8	.44	.36	.03	.08	.89	.48
		24.0	8	1.25	1.37	1.05	1.65	1.47	.30
		24.0	8	.88	1.21	.66	.09	2.92	1.17
	Fall	19.2	8	3.03	2.51	4.06	.57	1.23	4.17
		21.9	8	.71	2.58	.05	1.60	8.68**	.00
		24.0	8	2.26	.48	.85	.04	.38	.67
Lihue	Spring	18.0	8	.44	.81	2.10	.30	.00	.84
		22.1	8	2.32	.17	.15	.07	.23	.22
		24.0	8	.77	.37	.13	.14	.47	.73
	Fall	18.2	8	.81	.68	1.81	.04	.13	.73
		20.5	8	1.47	1.33	.03	3.92	.91	.45
		23.7	8	.57	1.00	2.42	.81	.72	.03
Kekaha	Spring	16.9	8	1.87	3.79	2.00	.01	13.00*	.14
		22.8	5	1.72	.78	.05	.17	2.38	.51
		24.3	8	4.89	3.04	9.03	3.01	.03	.09
	Fall	18.2	8	.91	.58	.08	1.40	.66	.18
		21.9	8	.84	3.42*	3.38	9.13*	.03	1.13
		24.2	8	.45	.16	.21	.09	.13	.18
Oahu	Spring	17.0	8	.88	.46	1.71	.04	.08	.02
		21.8	8	2.98	3.74	4.21	3.08	.20	7.48
		24.6	8	6.09	1.88	.72	2.94	1.33	2.53
	Fall	18.2	8	1.65	.51	.12	.20	.57	1.13
		21.5	8	5.46	7.43	.06	4.95	15.96	8.76
		24.2	8	2.84	7.67	2.31	4.95	18.00*	5.42
Pioneer	Spring	18.1	8	2.40	2.11	5.12	.38	2.31	.63
		21.7	8	2.11	3.46	1.28	9.13	3.29	.13
		24.8	8	1.24	1.12	2.31	.46	.32	1.40
	Fall	18.4	8	2.36	1.93	.72	3.84	.09	3.08
		21.4	8	1.40	1.96	3.13	.03	2.68	1.98
		24.0	8	4.90	.90	.05	1.71	1.77	.05
Olaa	Spring	17.8	8	.26	.70	1.45	.14	.60	.60
		21.6	8	.26	1.55*	.02	.00	5.61**	.57
		26.1	8	2.14	.33	.05	1.13	.00	.12
	Fall	18.0	8	.63	.63	.10	2.35	.08	.00
		21.1	8	.80	.28	.05	.08	.09	.88
		24.0	8	.36	.39	.50	.11	.76	.20
			Avg.	1.79	1.71	1.44	1.63	2.44	1.31
Olokele	Spring	25.1	23	5.38	3.83	.91	.01	11.79	2.61
		df.		309	148	37	37	37	37
		Wgtd. Avg.		2.06	1.77	1.44	1.59	2.70	1.34

Table VII

ERROR, NxK, AND AxNxK MEAN SQUARES FROM THE COMBINED ANALYSES OVER AGES OF HARVEST FOR THE SIX TESTS ON AMERICAN FACTORS PLANTATIONS

		Mean Squares For								
		TCA			Y%C			TSA		
Plantation	Planting	Error	AxNxK	NxK	Error	AxNxK	NxK	Error	AxNxK	NxK
Grove Farm	Spring	47.75	27.95	90.28	.44	.03	.34	.83	.49	1.63
	Fall	135.77	220.72	79.40	.66	.25	.86	1.95	2.12	1.34
Kekaha	Spring	140.28	174.14	137.29	1.30	.95	.34	2.98	2.28	3.05
	Fall	25.21	43.12	5.66	.69	.71	1.08	.73	1.23	1.71
Lihue	Spring	83.46	51.45	28.81	.24	.35	.03	1.17	.51	.32
	Fall	80.26	102.70	51.07	.41	.92	.40	.95	1.19	.63
Oahu	Spring	200.98	434.72	146.29	.84	1.18	1.23	3.31	2.70	.68
	Fall	108.08	446.66**	38.43	1.24	1.04	.94	3.31	6.90	1.82
Olaa	Spring	53.43	45.32	76.52	.65	.97	.63	.89	.76	1.05
	Fall	40.09	24.46	144.00*	.57	.33	.46	.60	.37	.56
Pioneer	Spring	123.83	128.63	37.09	.72	.53	1.55	1.92	2.17	2.35
	Fall	173.94	131.92	108.99	.94	1.74	.62	2.89	1.57	1.64
Average		101.09	152.65	78.65	.72	.75	.71	1.79	1.86	1.40

Table VIII

ERROR, NxK, AND AxNxK MEAN SQUARES FROM THE COMBINED ANALYSES OVER AGES OF HARVEST AND TIMES OF PLANTING FROM THE SIX TESTS ON THE AMERICAN FACTORS PLANTATIONS

	Mean Squares For								
	TCA			Y%C			TSA		
Plantation	Error	AxNxK	NxK	Error	AxNxK	NxK	Error	AxNxK	NxK
Grove Farm	91.76	135.00	24.95	.55	.07	.98	1.42	1.56	1.27
Kekaha	78.81	148.87	69.80	.99	1.04	.26	1.78	2.25	1.47
Lihue	81.86	80.18	17.46	.32	.70*	.37	1.06	1.05	.42
Oahu	154.53	548.23**	98.23	1.04	1.24	1.57	3.31	4.64	.64
Olaa	46.76	25.23	41.97	.72	.46	.99	.74	.73	.93
Pioneer	148.89	59.66	73.09	.83	1.65	1.46	2.40	.41	6.83*
Average	100.44	166.20	54.25	.74	.86	.94	1.78	1.77	1.93

PLANT AND SOIL COMPOSITION RELATIONSHIPS AS APPLIED TO CANE FERTILIZATION

L. D. Baver

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